

NOVEL ORGANIC ANION TRANSPORT PROTEINS

This application claims priority from provisional U.S. Application Serial No. 5 60/135,081, filed May 20, 1999, which is incorporated herein by reference in its entirety.

Field of the Invention

The invention claims isolated nucleic acid encoding all or a portion of novel 10 members of the organic anion transport protein (“OATP”) designated OATP2, OATP-RP1, OATP-RP2, OATP-RP3, OATP-RP4 and OATP-RP5. Also claimed are vectors containing the nucleic acid sequences, host cells containing the vectors and polypeptides having all or part of the amino acid sequence of OATP2, OATP-RP1, OATP-RP2, OATP-RP3, OATP-RP4 and OATP-RP5. Tissue expression of the 15 transporter is described as well as some of its substrates. Also claimed are uses for these novel OATPs, including for targeting drugs to specific tissues, for modulating the concentration of endogenous substrates, and for identifying a substrate capable of being transported by a novel OATP of the invention.

Background of the Invention

The liver functions in the clearance of a large variety of metabolic products, 20 drugs and other xenobiotics by transporting them across the sinusoidal membrane into the hepatocyte. Several classes of transport systems have been described that mediate these processes including the Na⁺/taurocholate cotransporter polypeptide, NTCP, in rat and human liver (Hagenbuch, B., et al. (1991) *Proc. Natl. Acad. Sci. USA* 25 88:10629-33; Hagenbuch, B. et al., (1994) *J. Clin. Invest.* 93:1326-31) and a family of organic anion transporting polypeptides (OATPs) that are principally expressed in liver, kidney and brain, and transport a broad spectrum of substrates in a sodium-independent manner (Meier, P.J., et al., (1997) *Hepatology* 26:1667-77; Wolkoff, 30 A.W., (1996) *Semin. Liver Dis.* 16:121-127). The distribution of this latter family of

transporters in liver, kidney and choroid plexus in the brain is thought to reflect common physiological requirements of these organs for the clearance of a multitude of organic anions. There are three OATP isoforms in the rat: roatp1 (Jacquemin, E., et al., (1994) *Proc. Natl. Acad. Sci. USA* 91:133-37); roatp2 (Noe, B.A., et al., (1997) *Proc. Natl. Acad. Sci. USA* 94:10346-50; and roatp3 (Abe, T., et al., (1998) *J. Biol. Chem.* 273:11395-401). In addition to bile acids, OATPs are known to transport a variety of other compounds. These include, depending on the transporter, unconjugated and conjugated steroids such as estrone sulfate, estradiol-17B-glucuronide, aldosterone, and cardiac glycosides (Boussuyt, X., et al., (1996) *J. Pharmacol. Exp. Ther.* 276:891-6; Boussuyt, X. (1996) *J. Hepatol.* 25:733-8; Kanai, N., et al., (1996) *Am. J. Physiol.* 270:F319-F325; Kanai, N., et al., (1996) *Am. J. Physiol.* 270:F326-F331; Noe, B.A., et al., (1997) *Proc. Natl. Acad. Sci. USA* 94:10346-50). Bromosulfophthalien (Jacquemin, E., et al., (1994) *Proc. Natl. Acad. Sci. USA* 91:133-7); mycotoxin (Kontaxi, M., et al., (1996) *J. Pharmacol. Exp. Ther.* 279:1507-13); leukotriene C₄ (Li, L., et al., (1998) *J. Biol. Chem.* 273:16184-91); and thyroid hormone (Abe, T., et al., (1998) *J. Biol. Chem.* 273:11395) are additional substrates.

Several proteins have been identified. Jacquemin, E., et al., (1994) *Proc. Natl. Acad. Sci. U.S.A.*, 91:133-137 reported the first cloning and identification of a member of the OATP transporter family, namely the rat oatp1. The first cloning and identification of a human OATP was reported in Kullak-Ublick, G.A., et al., (1995) *Gastroenterology*, 109:1274-1282. Its expression was found in liver, kidney brain and other organs. The authors concluded, based on substrate specificities, that it was not the human orthologue of rat oatp1.

Substrate specificities of rat oatp1 are discussed in Kullak-Ublick, G.A. et al., (1994) *Hepatology*, 20:411-416, while substrate specificities of human OATP are discussed in Bossuyt, X., et al., (1996) *J. Hepatol.*, 25:733-738.

Data was later discovered showing that rat oatp1 is involved in the transport of steroids (Bossuyt, X., et al., (1996) *J. Pharmacol. Exp. Ther.*, 276:891-896), and that human OATP acts as a transporter for the psychoactive hormone DHEAS (Kullak-Ublick, G.A., et al., (1998) *FEBS Lett.*, 424:173-176). For a review of the OATP

family and organic anion transport in the liver, see Wolkoff, A.W., (1996) *Semin. Liver Dis.*, 16:121-127.

A third rat OATP isoform that was shown to transport thyroid hormones T3 and T4 was cloned and reported in Abe,T., et al., (1998) *J. Biol. Chem.*, 273:22395-5 22401.

All references cited herein, whether *supra* or *infra*, are hereby incorporated by reference in their entirety.

Summary of the Invention

The present invention encompasses novel organic anion transport proteins (“OATP”) and polynucleotides encoding said OATPs. The OATPs disclosed herein are designated OATP2, OATP-RP2, OATP-RP3, OATP-RP4, OATP-RP5 and OATP-RP1. A polynucleotide sequence of each OATP is disclosed herein, along with the deduced amino acid sequence. The cDNAs encoding the OATPs of the present invention have been deposited with the American Type Culture Collection and given Accession Numbers ATCC 207213 (OATP2), ATCC 207212 (OATP-RP2), ATCC 207209 (OATP-RP3), ATCC 207210 (OATP-RP4), ATCC 207211 (OATP-RP5), and ATCC 207214 (OATP-RP1).

The present inventors sequenced the cDNAs encoding the novel OATPs and determined the primary sequence of the deduced proteins. Disclosed herein are the nucleic acid sequence (SEQ ID NO:1) and amino acid sequence (SEQ ID NO:2) of OATP2; the nucleic acid sequence (SEQ ID NO:3) and amino acid sequence (SEQ ID NO:4) of OATP-RP2; the nucleic acid sequence (SEQ ID NO:5) and amino acid sequence (SEQ ID NO:6) of OATP-RP3; the nucleic acid sequence (SEQ ID NO:7) and amino acid sequence (SEQ ID NO:8) of OATP-RP4; the nucleic acid sequence (SEQ ID NO:9) and amino acid sequence (SEQ ID NO:10) of OATP-RP5; and the nucleic acid sequence (SEQ ID NO:11) and amino acid sequence (SEQ ID NO:12) of OATP-RP1.

The OATPs of the present invention can be produced by: (1) inserting the cDNA of a disclosed OATP into an appropriate expression vector; (2) transfecting the expression vector into an appropriate transfection host(s); (3) growing the transfected

host(s) in appropriate culture media; and (4) assaying the transport activity in the transfected cells.

The present invention therefore provides a purified and isolated nucleic acid molecule, preferably a DNA molecule, having a sequence which codes for an OATP, or an oligonucleotide fragment of the nucleic acid molecule which is unique to an OATP of the invention. In a preferred embodiment of the invention, the purified and isolated nucleic acid molecule has the sequence as shown in SEQ ID NO:1 (OATP2). In another preferred embodiment, the purified and isolated nucleic acid molecule has the sequence as shown in SEQ ID NO:3 (OATP-RP2). In still another preferred embodiment the purified and isolated nucleic acid molecule has the sequence as shown in SEQ ID NO:5 (OATP-RP3). In still another preferred embodiment of the present invention the purified and isolated nucleic acid molecule has the nucleotide sequence as shown in SEQ ID NO:7 (OATP-RP4). In still another preferred embodiment the purified and isolated nucleic acid molecule has the sequence as shown in SEQ ID NO:9 (OATP-RP5). In still another preferred embodiment of the present invention the purified and isolated nucleic acid molecule has the nucleotide sequence as shown in SEQ ID NO:11 (OATP-RP1).

The invention also contemplates a double stranded nucleic acid molecule comprising a nucleic acid molecule of the invention or an oligonucleotide fragment thereof hydrogen bonded to a complementary nucleotide base sequence.

The terms “isolated and purified nucleic acid”, “isolated and purified polynucleotide”, “substantially pure nucleic acid”, and “substantially pure polynucleotide”, e.g., substantially pure DNA, refer to a nucleic acid molecule which is one or both of the following: (1) not immediately contiguous with either one or both of the sequences, e.g., coding sequences, with which it is immediately contiguous (i.e., one at the 5’ end and one at the 3’end) in the naturally occurring genome of the organism from which the nucleic acid is derived; or (2) which is substantially free of a nucleic acid sequence with which it occurs in the organism from which the nucleic acid is derived. The term includes, for example, a recombinant DNA which is incorporated into a vector, e.g., into an autonomously replicating plasmid or virus, or into the genomic DNA of a prokaryote or eukaryote, or which exists as a separate molecule (e.g., a cDNA or a genomic DNA fragment

produced by PCR or restriction endonuclease treatment) independent of other DNA sequences. Substantially pure or isolated and purified DNA also includes a recombinant DNA which is part of a hybrid gene encoding additional OATP sequence.

5 The present invention provides in one embodiment: (a) an isolated and purified nucleic acid molecule comprising a sequence encoding all or a portion of a protein having the amino acid sequence as shown in SEQ ID NO:2 (OATP2); (b) nucleic acid sequences complementary to (a); (c) nucleic acid sequences which exhibit at least 80%, more preferably at least 90%, more preferably at least 95%, and
10 most preferably at least 98% sequence identity to (a); or (d) a fragment of (a) or (b) that is at least 18 bases and which will hybridize to (a) or (b) under stringent conditions.

The degree of homology (percent sequence identity) between two sequences may be determined, for example, by comparing the two sequences using computer
15 programs commonly employed for this purpose. One suitable program is the GAP computer program described by Devereux et al., (1984) *Nucl. Acids Res.* 12:387. The GAP program utilizes the alignment method of Needleman and Wunsch (1970) *J. Mol. Biol.* 48:433, as revised by Smith and Waterman (1981) *Adv. Appl. Math.* 2:482. Briefly, the GAP program defines percent identity as the number of aligned symbols
20 (i.e., nucleotides or amino acids) which are identical, divided by the total number of symbols in the shorter of the two sequences.

As used herein the term "stringent conditions" encompasses conditions known in the art under which a nucleotide sequence will hybridize to: (a) an isolated and purified nucleic acid molecule comprising a sequence encoding a protein having the
25 amino acid sequence as shown herein, or to (b) a nucleic acid sequence complementary to (a). Screening polynucleotides under stringent conditions may be carried out according to the method described in Nature, 313:402-404 (1985). Polynucleotide sequences capable of hybridizing under stringent conditions with the polynucleotides of the present invention may be, for example, allelic variants of the
30 disclosed DNA sequences, or may be derived from other sources. General techniques of nucleic acid hybridization are disclosed by Sambrook et al., "Molecular Cloning: A Laboratory Manual", 2nd Ed., Cold Spring Harbor Laboratory, Cold Spring Harbor,

New York (1984); and by Haymes et al., "Nucleic Acid Hybridization: A Practical Approach", IRL Press, Washington, D.C. (1985), which references are incorporated herein by reference.

The present invention provides in another embodiment: (a) an isolated and purified nucleic acid molecule comprising a sequence encoding all or a portion of a protein having the amino acid sequence as shown in SEQ ID NO:4 (OATP-RP2); (b) nucleic acid sequences complementary to (a); (c) nucleic acid sequences which are at least 80%, more preferably at least 90%, more preferably at least 95%, and most preferably at least 98% sequence identity to (a); or (d) a fragment of (a) or (b) that is at least 18 bases and which will hybridize to (a) or (b) under stringent conditions.

The present invention provides in another embodiment: (a) an isolated and purified nucleic acid molecule comprising a sequence encoding all or a portion of a protein having the amino acid sequence as shown in SEQ ID NO:6 (OATP-RP3); (b) nucleic acid sequences complementary to (a); (c) nucleic acid sequences which are at least 80%, more preferably at least 90%, more preferably at least 95%, and most preferably at least 98% sequence identity to (a); or (d) a fragment of (a) or (b) that is at least 18 bases and which will hybridize to (a) or (b) under stringent conditions.

The present invention provides in another embodiment: (a) an isolated and purified nucleic acid molecule comprising a sequence encoding all or a portion of a protein having the amino acid sequence as shown in SEQ ID NO:8 (OATP-RP4); (b) nucleic acid sequences complementary to (a); (c) nucleic acid sequences which are at least 80%, more preferably at least 90%, more preferably at least 95%, and most preferably at least 98% sequence identity to (a); or (d) a fragment of (a) or (b) that is at least 18 bases and which will hybridize to (a) or (b) under stringent conditions.

The present invention provides in another embodiment: (a) an isolated and purified nucleic acid molecule comprising a sequence encoding all or a portion of a protein having the amino acid sequence as shown in SEQ ID NO:10 (OATP-RP5); (b) nucleic acid sequences complementary to (a); (c) nucleic acid sequences which are at least 80%, more preferably at least 90%, more preferably at least 95%, and most preferably at least 98% sequence identity to (a); or (d) a fragment of (a) or (b) that is at least 18 bases and which will hybridize to (a) or (b) under stringent conditions.

The present invention provides in another embodiment: (a) an isolated and purified nucleic acid molecule comprising a sequence encoding all or a portion of a protein having the amino acid sequence as shown in SEQ ID NO:12 (OATP-RP1); (b) nucleic acid sequences complementary to (a); (c) nucleic acid sequences which are at least 80%, more preferably at least 90%, more preferably at least 95%, and most preferably at least 98% sequence identity to (a); or (d) a fragment of (a) or (b) that is at least 18 bases and which will hybridize to (a) or (b) under stringent conditions.

5 The present invention also provides: (a) a purified and isolated nucleic acid molecule comprising a sequence as shown in SEQ ID NO:1 (OATP2); (b) nucleic acid sequences complementary to (a); (c) nucleic acid sequences having at least 80%, more preferably at least 90%, more preferably at least 95%, and most preferably at least 98% sequence identity to (a); or (d) a fragment of (a) or (b) that is at least 18 bases and which will hybridize to (a) or (b) under stringent conditions.

10 The present invention further provides: (a) a purified and isolated nucleic acid molecule comprising a sequence as shown in SEQ ID NO:3 (OATP-RP2); (b) nucleic acid sequences complementary to (a); (c) nucleic acid sequences having at least 80%, more preferably at least 90%, more preferably at least 95%, and most preferably at least 98% sequence identity to (a); or (d) a fragment of (a) or (b) that is at least 18 bases and which will hybridize to (a) or (b) under stringent conditions.

15 The present invention further provides: (a) a purified and isolated nucleic acid molecule comprising a sequence as shown in SEQ ID NO:5 (OATP-RP3); (b) nucleic acid sequences complementary to (a); (c) nucleic acid sequences having at least 80%, more preferably at least 90%, more preferably at least 95%, and most preferably at least 98% sequence identity to (a); or (d) a fragment of (a) or (b) that is at least 18 bases and which will hybridize to (a) or (b) under stringent conditions.

20 The present invention further provides: (a) a purified and isolated nucleic acid molecule comprising a sequence as shown in SEQ ID NO:7 (OATP-RP4); (b) nucleic acid sequences complementary to (a); (c) nucleic acid sequences having at least 80%, more preferably at least 90%, more preferably at least 95%, and most preferably at least 98% sequence identity to (a); or (d) a fragment of (a) or (b) that is at least 18 bases and which will hybridize to (a) or (b) under stringent conditions.

The present invention further provides: (a) a purified and isolated nucleic acid molecule comprising a sequence as shown in SEQ ID NO:9 (OATP-RP5); (b) nucleic acid sequences complementary to (a); (c) nucleic acid sequences having at least 80%, more preferably at least 90%, more preferably at least 95%, and most preferably at least 98% sequence identity to (a); or (d) a fragment of (a) or (b) that is at least 18 bases and which will hybridize to (a) or (b) under stringent conditions.

5 The present invention further provides: (a) a purified and isolated nucleic acid molecule comprising a sequence as shown in SEQ ID NO:11 (OATP-RP1); (b) nucleic acid sequences complementary to (a); (c) nucleic acid sequences having at least 80%, more preferably at least 90%, more preferably at least 95%, and most preferably at least 98% sequence identity to (a); or (d) a fragment of (a) or (b) that is at least 18 bases and which will hybridize to (a) or (b) under stringent conditions.

10 The present invention additionally covers polynucleotides and amino acid sequences of the present invention having one or more structural mutations including 15 replacement, deletion or insertion mutations. For example, a signal peptide may be deleted, or conservative amino acid substitutions may be made to generate a protein that is still biologically competent or active.

20 The invention further contemplates a recombinant molecule comprising a nucleic acid molecule of the present invention or an oligonucleotide fragment thereof and an expression control sequence operatively linked to the nucleic acid molecule or oligonucleotide fragment. A transformant host cell including a recombinant molecule of the invention is also provided.

25 In another aspect, the invention features a cell or purified preparation of cells which include a novel gene encoding an OATP of the present invention, or which otherwise misexpresses a gene encoding an OATP of the present invention. The cell preparation can consist of human or non-human cells, e.g., rodent cells, e.g., mouse or rat cells, rabbit cells, non-human primate cells, or pig cells. In preferred embodiments, the cell or cells include an OATP transgene, e.g., a heterologous form of an OATP gene, e.g., a gene derived from humans (in the case of a non-human cell). 30 The OATP transgene can be misexpressed, e.g., overexpressed or underexpressed. In other preferred embodiments, the cell or cells include a gene which misexpresses an endogenous OATP gene, e.g., a gene that expression of which is disrupted, e.g., a

knockout. Such cells can serve as a model for studying disorders which are related to mutated or misexpressed OATP alleles for use in drug screening.

Still further, the invention provides plasmids which comprise the nucleic acid molecules of the invention. Also encompassed within the invention are vectors 5 comprising the nucleic acid sequences disclosed herein, as well as host cells comprising said vectors.

The present invention also includes a novel OATP of the present invention, or an active part thereof. A biologically competent or active form of the protein or part thereof is also referred to herein as an “active OATP or part thereof”.

10 The invention further contemplates antibodies having specificity against an epitope of an OATP of the present invention or part of the protein. These antibodies may be polyclonal or monoclonal. The antibodies may be labeled with a detectable substance and they may be used, for example, to detect a novel OATP of the invention in tissue and cells. Additionally, the antibodies of the present invention, or 15 portions thereof, may be used to make targeted antibodies that destroy OATP expressing cells (e.g., antibody-toxin fusion proteins, or radiolabelled antibodies).

The invention also permits the construction of nucleotide probes which encode 20 part or all of a novel OATP protein of the invention or a part of the protein. Thus, the invention also relates to a probe comprising a nucleotide sequence coding for a protein, which displays the properties of a novel OATP of the invention or a peptide unique to the protein. The probe may be labeled, for example, with a detectable (e.g., radioactive) substance and it may be used to select from a mixture of nucleotide sequences a nucleotide sequence coding for a protein which displays the properties of a novel OATP of the invention.

25 The present invention also provides a transgenic non-human animal (e.g., a rodent, e.g., a mouse or a rat, a rabbit or a pig) or embryo all of whose germ cells and somatic cells contain a recombinant molecule of the invention, preferably a recombinant molecule comprising a nucleic acid molecule of the present invention encoding an OATP of the invention or part thereof. The recombinant molecule may 30 comprise a nucleic acid sequence encoding an OATP of the present invention with a structural mutation, or may comprise a nucleic acid sequence encoding an OATP of the invention or part thereof and one or more regulatory elements which differ from

the regulatory elements that drive expression of the native protein. In another preferred embodiment, the animal has an OATP gene which is misexpressed or not expressed, e.g., a knockout. Such transgenic animals can serve as a model for studying disorders that are related to mutated or misexpressed OATPs of the present invention.

The invention still further provides a method for identifying a substance which is capable of binding a novel OATP of the invention, comprising reacting a novel OATP of the invention or part of the protein under conditions which permit the formation of a complex between the substance and a novel OATP protein or part of the protein, and assaying for substance-OATP complexes, for free substance, for non-complexed OATP, or for activation of an OATP.

An embodiment of the invention provides a method for identifying substrates which are capable of binding to a novel OATP protein of the invention, isoforms thereof, or part of the protein, said method comprising reacting a novel OATP protein of the invention, isoforms thereof, or part of the protein, with at least one substrate which potentially is capable of binding to the protein, isoform, or part of the protein, under conditions which permit the formation of substrate-transporter protein complexes, and assaying for substrate-transporter protein complexes, for free substrate, for non-complexed OATP protein, or for activation of an OATP. In a preferred embodiment of the method, substrates are identified which are capable of binding to and being transported by a novel OATP protein of the invention, isoforms thereof, or part of the protein.

The invention also provides methods for screening potentially useful pharmacological agonists or antagonists of the OATPs of the present invention. The method comprises testing potential agents by adding the agent to be tested to a cell expressing a novel OATP of the present invention in the presence of a compound known to be transported by an OATP of the invention, and measuring the augmentation or inhibition of transport of the known compound.

An OATP of the present invention is also useful to identify compounds that may be transported into an organ, e.g., the liver. Compounds that are found to be actively transported into the liver are useful as carriers for other therapeutics targeting the liver.

Also included within the scope of the present invention is a composition which includes an OATP of the present invention, a fragment thereof (or a nucleic acid encoding said OATP or fragment thereof) and one or more additional components, e.g., a carrier, diluent or solvent. The additional component can be one that renders

5 the composition useful for in vitro, in vivo, pharmaceutical or veterinary use.

Encompassed within the present invention are agonists and antagonists of an OATP of the present invention. Pharmacological agonists or antagonists are useful to increase or decrease the flow of compounds transported by an OATP of the present invention. Said agonists and/or antagonists of the present invention are preferably

10 administered with an acceptable carrier, diluent or solvent.

In another aspect, the present invention relates to a method of treating a mammal, e.g., a human, at risk for a disorder, e.g., a disorder characterized by aberrant or unwanted level or biological activity of an OATP of the present invention. Additionally, encompassed within the invention is a method of treating a mammal,

15 e.g., a human, at risk for disorders of the liver. Since OATP2 is expressed exclusively in the liver, compounds that are optimized for OATP2 are useful to target hepatic delivery. These compounds in themselves may be useful therapeutics, or may be useful to chaperone other therapeutic compounds to the liver. In addition, blocking OATP2-compound interactions could provide benefit by decreasing its first-pass

20 extraction by the liver and, thus, increasing plasma concentrations and prolonging the systemic half-life of a drug.

Also within the scope of the present invention are fusion proteins comprising all or a portion of an OATP of the present invention.

25 The primary object of the present invention is the identification of new human OATPs, as identified by the nucleic acid and amino acid sequences disclosed herein. Additional objects of the invention are the methods of using the cDNA, the OATP proteins, monoclonal antibodies specific for the novel OATPs, fusion proteins comprising a portion of the OATP protein of the present invention, and agonists

30 and/or antagonists of the novel OATPs as described above.

Brief Description of the Figures

Figure 1 is a Northern blot showing the mRNA tissue distribution of OATP2, OATP-RP1, OATP-RP2, OATP-RP4, and OATP-RP5. The tissues corresponding to the abbreviations above the lanes are indicated below.

- 5 Figure 2 shows that OATP2 transports pravastatin, dehydroepiandrosterone sulfate (DHEAS), taurocholate and thyroid hormone (T₄). Figure 2A shows specific uptake of [³H]-pravastatin and [³H]-DHEAS. Figure 2B shows specific uptake of [³H]-taurocholate. Panel 2C shows specific uptake of [¹²⁵I]-thyroid hormone (T₄). The uptake of radiolabeled substrate for 5 minutes into cells transfected with
10 pCEPOATP-RP1 or empty vector (MOCK) was determined in the absence (solid bars) and presence (open bars) of excess unlabeled substrate.

Figure 3 shows a sequence alignment of OATP family members. The protein sequences of human OATP2, OATP-RP1, OATP-RP2, OATP-RP3, OATP-RP4, and OATP-RP5 are aligned with the other known OATP family members. Also shown is
15 a consensus sequence in bold. A consensus is indicated if at least 6 out of the 12 sequences are identical at a given position. A residue is capitalized if it agrees with the consensus.

Detailed Description of the Invention

- 20 The following definitions apply to the terms used throughout this specification, unless otherwise defined in specific instances:

“cloning” - isolation of a particular gene from genetic material, for example a genome, genomic library, or cDNA library into a plasmid or other vector;

25 “coding region” – the region of a nucleic acid sequence that codes for an active protein;

“OATP” – organic anion transport protein;

“stringent conditions” (as used concerning nucleic acid hybridization)—
Southern blotting washed in 0.1 X SSC and 0.1% SDS at a temperature of at least about 65° C. See Maniatis et al., Molecular Cloning: A Laboratory Manual, Cold
30 Spring Harbor Laboratory, Cold Spring Harbor, NY (1982); one skilled in the relevant art would recognize that less stringent conditions (e.g., 1X or 2X SSC,

0.1%SDS) may be employed in using the novel sequences disclosed herein to identify nucleic acid sequences encoding novel OATPs.

"Northern blotting"—a method of identifying particular RNA fragments by hybridization with a complementary nucleic acid, typically a cDNA or an
5 oligonucleotide;

"open reading frame" or "ORF"—a DNA sequence containing a series of nucleotide triplets coding for amino acids and lacking any termination codes;

"plasmid"—cytoplasmic, autonomously replicating DNA elements found in microorganisms;

10 "promoter"—a region on DNA at which RNA polymerase binds and initiates transcription; and

"Southern blotting"—a method of identifying particular DNA fragments by hybridization with a complementary nucleic acid, typically a cDNA or an oligonucleotide;

15 "transport" - the movement of a substance across a biological membrane as determined by measuring the redistribution of such a substance across the membrane upon exposure to a transporter.

For definitions of other terms in this specification, see F. Sherman *et al.*,
Laboratory Course Manual for Methods in Yeast Genetics, Cold Spring Harbor
20 Laboratory, Cold Spring Harbor, NY (1987) and Lewin, B., Genes IV, Oxford University Press, Oxford (1990). For the definitions of abbreviations, see
Aldrichimica Acta, Vol. 17, No. 1 (1984).

Use and utility

25 The amino acid sequences of the novel organic anion transport proteins of the present invention are aligned with known transporters of this family in Figure 3. The degree of sequence homology between the sequences of the present invention and known organic anion transporters indicates that the proteins of the present invention are organic anion transporters.

30 It is believed by those skilled in the art that OATP proteins may be involved in the transport of compounds into the liver. Persons of ordinary skill in the art can use the OATP proteins of the present invention to assay for agents that may increase or

decrease the rate of transport of compounds into the liver, or for compounds that are transported by the OATPs of the present invention that are useful as carriers for other compounds that are desired to be carried to a specific organ (e.g., the liver).

Therefore, agents that increase or decrease the rate of substrate transport by
5 the OATPs of the present invention, or agents identified as carriers, are useful in the treatment of liver disease.

Because some of the OATPs of the present invention are organ specific/selective (e.g., OATP2 - liver; OATP-RP4 - heart and skeletal muscle, and OATP-RP5 - brain and testis), compound specificity is built into any specific
10 substrate of these OATPs and into molecular carriers transported by these OATPs. An agent transported by the above OATPs of the present invention would thus be delivered to the tissues in which they are expressed and not to tissues lacking the above OATPs, thereby achieving tissue specific targeting.

The OATP nucleic acids of the present invention, or antisense nucleic acids,
15 may be useful therapeutic or diagnostic agents. For such gene therapy, the nucleic acids may be incorporated into vectors and/or formulated as described below and in further detail in the art.

The present invention also provides a basis for diagnostic genetic screens for predicting response to drugs. At least one of the transporters disclosed and claimed
20 herein is a transporter of a known drug (i.e., OATP2 transports pravastatin into hepatocytes). Other transporters disclosed herein may similarly transport additional drugs into tissues. Persons skilled in the art can: (1) screen the transporter genes for allelic variants (genotypes) in the general population by various sequencing methods; and (2) determine the association of these transporter genotypes in patients with
25 response to the transported drug in clinical trials. Particular allelic variants may be more or less effective in transporting a drug, which would be related to drug efficacy. Thus, genotyping of the claimed transporters could form the basis of a clinical diagnostic test to predict a patient's response to drug therapy.

Persons skilled in the art can use the polypeptides and nucleic acids of this
30 invention to prepare vectors, cells or cell lines, and antibodies. All of these are useful in assays for identification of OATP positive and negative modulators (i.e., agonists and/or antagonists) and OATP carriers. The term "positive modulator" as used herein

refers to an agent or compound that increases the rate or amount of transport of a compound into an organ, e.g., the liver, or an agent or compound that decreases the rate or amount of transport of a compound into an organ. The term "negative modulator" refers to a compound that is joined to a second compound to prevent the 5 second compounds transport into or out of cells. The term "carrier" as used herein refers to an agent or compound that is transported by an OATP of the present invention and that is capable of being joined to or associated with another compound to chaperone that other compound into an organ, e.g., the liver. A carrier includes an agent that is used to transport a compound into an organ that is otherwise not 10 transported into said organ, and includes an agent that increases the transport of a compound into an organ that is capable of being transported by an OATP.

One can administer OATP modulators and carriers to various mammalian species, such as monkeys, dogs, cats, mice, rats, humans, etc. By known methods, persons skilled in the pharmaceutical art can incorporate OATP modulators and 15 carriers in a conventional systemic dosage form, such as a tablet, capsule, elixir or injectable formulation. The above dosage forms will also include any necessary physiologically acceptable carrier material, excipient, lubricant, buffer, antibacterial, bulking agent (such as mannitol), anti-oxidants (ascorbic acid or sodium bisulfite) or the like.

20 Process of preparation

In general

This specification describes the cloning and functional expression of full-length human cDNA clones of OATPs, preferably the nucleic acid sequence of OATP2 (SEQ ID NO:1), the amino acid sequence of OATP2 (SEQ ID NO:2), the 25 nucleic acid sequence of OATP-RP2 (SEQ ID NO:3), the amino acid sequence of OATP-RP2 (SEQ ID NO:4), the nucleic acid sequence of OATP-RP3 (SEQ ID NO:5), the amino acid sequence of OATP-RP3 (SEQ ID NO:6), the nucleic acid sequence of OATP-RP4 (SEQ ID NO:7), the amino acid sequence of OATP-RP4 (SEQ ID NO:8), the nucleic acid sequence of OATP-RP5 (SEQ ID NO:9), the amino 30 acid sequence of OATP-RP5 (SEQ ID NO:10), the nucleic acid sequence of OATP-RP1 (SEQ ID NO:11), and the amino acid sequence of OATP-RP1 (SEQ ID NO:12).

DNA clones comprising nucleotide sequences encoding the OATPs described above were deposited with the American Type Culture Collection ("ATCC") (10801 University Blvd., Manassas, VA 20110-2209) on April 20, 1999, and given the following ATCC Accession Numbers: 207209 (OATP-RP3), 207210 (OATP-RP4), 5 207211 (OATP-RP5), 207212 (OATP-RP2), 207213 (OATP2), and 207214 (OATP-RP1). The deposit(s) referred to herein will be maintained under the terms of the Budapest Treaty on the International Recognition of the Deposit of Microorganisms for purposes of Patent Procedure. These deposits are provided merely as convenience to those of skill in the art and are not an admission that a deposit is required under 35 10 U.S.C. §112. The sequence of the polynucleotides contained in the deposited materials, as well as the amino acid sequence of the of the polypeptides encoded thereby, are incorporated herein by reference and are controlling in the event of any conflict with any description of sequences herein. A license may be required to make, use or sell the deposited materials, and no such license is hereby granted.

15 Nucleic acids

With the disclosed OATP gene sequences in hand, one skilled in the art can obtain OATP nucleic acids of this invention by known methods. Such methods include: (1) Southern and Northern blotting; (2) Western immunoblotting; (3) chemical synthesis; (4) synthesis by polymerase chain reaction (PCR) from primers; 20 (5) expression cloning; and (6) subtractive cDNA cloning.

Preferred nucleic acid sequences of the present invention include the following (preferably the coding sequences as shown below):

OATP2 (SEQ ID NOS:1 and 2):

25	CGGACGCGTG GGCAGACGCG TGGGTGCGCC ACGCGTCCGA CTTGTTGCAG TTGCTGTAGG ATTCTAAATC CAGGTGATTG TTTCAAACTG AGCATCAACA ACAAAAAACAT TTGTATGATA TCTATATTTC AATC ATG GAC CAA AAT CAA	50 100 149
	M D Q N Q	
30	CAT TTG AAT AAA ACA GCA GAG GCA CAA CCT TCA GAG AAT AAG H L N K T A E A Q P S E N K	191
	AAA ACA AGA TAC TGC AAT GGA TTG AAG ATG TTC TTG GCA GCT K T R Y C N G L K M F L A A	233
35	CTG TCA CTC AGC TTT ATT GCT AAG ACA CTA GGT GCA ATT ATT L S L S F I A K T L G A I I	275
40	ATG AAA AGT TCC ATC ATT CAT ATA GAA CGG AGA TTT GAG ATA M K S S I I H I E R R F E I	317

DB23(NP)

	TCC	TCT	TCT	CTT	GTT	GGT	TTT	ATT	GAC	GGA	AGC	TTT	GAA	ATT	359
	S	S	S	L	V	G	F	I	D	G	S	F	E	I	
5	GGA	AAT	TTG	CTT	GTG	ATT	GTA	TTT	GTG	AGT	TAC	TTT	GGA	TCC	401
	G	N	L	L	V	I	V	F	V	S	Y	F	G	S	
	AAA	CTA	CAT	AGA	CCA	AAG	TTA	ATT	GGA	ATC	GGT	TGT	TTC	ATT	443
	K	L	H	R	P	K	L	I	G	I	G	C	F	I	
10	ATG	GGA	ATT	GGA	GGT	GTT	TTG	ACT	GCT	TTG	CCA	CAT	TTC	TTC	485
	M	G	I	G	G	V	L	T	A	L	P	H	F	F	
	ATG	GGA	TAT	TAC	AGG	TAT	TCT	AAA	GAA	ACT	AAT	ATC	GAT	TCA	527
	M	G	Y	Y	R	Y	S	K	E	T	N	I	D	S	
15	TCA	GAA	AAT	TCA	ACA	TCG	ACC	TTA	TCC	ACT	TGT	TTA	ATT	AAT	569
	S	E	N	S	T	S	T	L	S	T	C	L	I	N	
20	CAA	ATT	TTA	TCA	CTC	AAT	AGA	GCA	TCA	CCT	GAG	ATA	GTG	GGA	611
	Q	I	L	S	L	N	R	A	S	P	E	I	V	G	
	AAA	GGT	TGT	TTA	AAG	GAA	TCT	GGG	TCA	TAC	ATG	TGG	ATA	TAT	653
	K	G	C	L	K	E	S	G	S	Y	M	W	I	Y	
25	GTG	TTC	ATG	GGT	AAT	ATG	CTT	CGT	GGA	ATA	GGG	GAG	ACT	CCC	695
	V	F	M	G	N	M	L	R	G	I	G	E	T	P	
	ATA	GTA	CCA	TTG	GGG	CTT	TCT	TAC	ATT	GAT	GAT	TTC	GCT	AAA	737
	I	V	P	L	G	L	S	Y	I	D	D	F	A	K	
30	GAA	GGA	CAT	TCT	TCT	TTG	TAT	TTA	GGT	ATA	TTG	AAT	GCA	ATA	779
	E	G	H	S	S	L	Y	L	G	I	L	N	A	I	
	GCA	ATG	ATT	GGT	CCA	ATC	ATT	GGC	TTT	ACC	CTG	GGA	TCT	CTG	821
35	A	M	I	G	P	I	I	G	F	T	L	G	S	L	
	TTT	TCT	AAA	ATG	TAC	GTG	GAT	ATT	GGA	TAT	GTA	GAT	CTA	AGC	863
	F	S	K	M	Y	V	D	I	G	Y	V	D	L	S	
40	ACT	ATC	AGG	ATA	ACT	CCT	ACT	GAT	TCT	CGA	TGG	GTT	GGA	GCT	905
	T	I	R	I	T	P	T	D	S	R	W	V	G	A	
	TGG	TGG	CTT	AAT	TTC	CTT	GTG	TCT	GGA	CTA	TTC	TCC	ATT	ATT	947
45	W	W	L	N	F	L	V	S	G	L	F	S	I	I	
	TCT	TCC	ATA	CCA	TTC	TTT	TTC	TTG	CCC	CAA	ACT	CCA	AAT	AAA	989
	S	S	I	P	F	F	F	L	P	Q	T	P	N	K	
50	CCA	CAA	AAA	GAA	AGA	AAA	GCT	TCA	CTG	TCT	TTG	CAT	GTG	CTG	1031
	P	Q	K	E	R	K	A	S	L	S	L	H	V	L	
	GAA	ACA	AAT	GAT	GAA	AAG	GAT	CAA	ACA	GCT	AAT	TTG	ACC	AAT	1073
	E	T	N	D	E	K	D	Q	T	A	N	L	T	N	
55	CAA	GGA	AAA	AAT	ATT	ACC	AAA	AAT	GTG	ACT	GGT	TTT	TTC	CAG	1115
	Q	G	K	N	I	T	K	N	V	T	G	F	F	Q	
	TCT	TTT	AAA	AGC	ATC	CTT	ACT	AAT	CCC	CTG	TAT	GTT	ATG	TTT	1157
60	S	F	K	S	I	L	T	N	P	L	Y	V	M	F	
	GTG	CTT	TTG	ACG	TTG	TTA	CAA	GTA	AGC	AGC	TAT	ATT	GGT	GCT	1199
	V	L	L	T	L	L	Q	V	S	S	Y	I	G	A	
65	TTT	ACT	TAT	GTC	TTC	AAA	TAC	GTA	GAG	CAA	CAG	TAT	GGT	CAG	1241
	F	T	Y	V	F	K	Y	V	E	Q	Q	Y	G	Q	
	CCT	TCA	TCT	AAG	GCT	AAC	ATC	TTA	TTG	GGA	GTC	ATA	ACC	ATA	1283

DB23(NP)

	P	S	S	K	A	N	I	L	L	G	V	I	T	I	
	CCT	ATT	TTT	GCA	AGT	GGA	ATG	TTT	TTA	GGA	GGA	TAT	ATC	ATT	1325
5	P	I	F	A	S	G	M	F	L	G	G	Y	I	I	
	AAA	AAA	TTC	AAA	CTG	AAC	ACC	GTT	GGA	ATT	GCC	AAA	TTC	TCA	1367
	K	K	F	K	L	N	T	V	G	I	A	K	F	S	
10	TGT	TTT	ACT	GCT	GTG	ATG	TCA	TTG	TCC	TTT	TAC	CTA	TTA	TAT	1409
	C	F	T	A	V	M	S	L	S	F	Y	L	L	Y	
	TTT	TTC	ATA	CTC	TGT	GAA	AAC	AAA	TCA	GTT	GCC	GGA	CTA	ACC	1451
	F	F	I	L	C	E	N	K	S	V	A	G	L	T	
15	ATG	ACC	TAT	GAT	GGA	AAT	AAT	CCA	GTG	ACA	TCT	CAT	AGA	GAT	1493
	M	T	Y	D	G	N	N	P	V	T	S	H	R	D	
	GTA	CCA	CTT	TCT	TAT	TGC	AAC	TCA	GAC	TGC	AAT	TGT	GAT	GAA	1535
20	V	P	L	S	Y	C	N	S	D	C	N	C	D	E	
	AGT	CAA	TGG	GAA	CCA	GTC	TGT	GGA	AAC	AAT	GGA	ATA	ACT	TAC	1577
	S	Q	W	E	P	V	C	G	N	N	G	I	T	Y	
25	ATC	TCA	CCC	TGT	CTA	GCA	GGT	TGC	AAA	TCT	TCA	AGT	GGC	AAT	1619
	I	S	P	C	L	A	G	C	K	S	S	S	G	N	
	AAA	AAG	CCT	ATA	GTG	TTT	TAC	AAC	TGC	AGT	TGT	TTG	GAA	GTA	1661
	K	K	P	I	V	F	Y	N	C	S	C	L	E	V	
30	ACT	GGT	CTC	CAG	AAC	AGA	AAT	TAC	TCA	GCC	CAT	TTG	GGT	GAA	1703
	T	G	L	Q	N	R	N	Y	S	A	H	L	G	E	
	TGC	CCA	AGA	GAT	GAT	GCT	TGT	ACA	AGG	AAA	TTT	TAC	TTT	TTT	1745
35	C	P	R	D	D	A	C	T	R	K	F	Y	F	F	
	GTT	GCA	ATA	CAA	GTC	TTG	AAT	TTA	TTT	TTC	TCT	GCA	CTT	GGA	1787
	V	A	I	Q	V	L	N	L	F	F	S	A	L	G	
40	GGC	ACC	TCA	CAT	GTC	ATG	CTG	ATT	GTT	AAA	ATT	GTT	CAA	CCT	1829
	G	T	S	H	V	M	L	I	V	K	I	V	Q	P	
	GAA	TTG	AAA	TCA	CTT	GCA	CTG	GGT	TTC	CAC	TCA	ATG	GTT	ATA	1871
	E	L	K	S	L	A	L	G	F	H	S	M	V	I	
45	CGA	GCA	CTA	GGA	GGA	ATT	CTA	GCT	CCA	ATA	TAT	TTT	GGG	GCT	1913
	R	A	L	G	G	I	L	A	P	I	Y	F	G	A	
	CTG	ATT	GAT	ACA	ACG	TGT	ATA	AAG	TGG	TCC	ACC	AAC	AAC	TGT	1955
50	L	I	D	T	T	C	I	K	W	S	T	N	N	C	
	GGC	ACA	CGT	GGG	TCA	TGT	AGG	ACA	TAT	AAT	TCC	ACA	TCA	TTT	1997
	G	T	R	G	S	C	R	T	Y	N	S	T	S	F	
55	TCA	AGG	GTC	TAC	TTG	GGC	TTG	TCT	TCA	ATG	TTA	AGA	GTC	TCA	2039
	S	R	V	Y	L	G	L	S	S	M	L	R	V	S	
	TCA	CTT	GTT	TTA	TAT	ATT	ATA	TTA	ATT	TAT	GCC	ATG	AAG	AAA	2081
	S	L	V	L	Y	I	I	L	I	Y	A	M	K	K	
60	AAA	TAT	CAA	GAG	AAA	GAT	ATC	AAT	GCA	TCA	GAA	AAT	GGA	AGT	2123
	K	Y	Q	E	K	D	I	N	A	S	E	N	G	S	
	GTC	ATG	GAT	GAA	GCA	AAC	TTA	GAA	TCC	TTA	AAT	AAA	AAT	AAA	2165
65	V	M	D	E	A	N	L	E	S	L	N	K	N	K	
	CAT	TTT	GTC	CCT	TCT	GCT	GGG	GCA	GAT	AGT	GAA	ACA	CAT	TGT	2207
	H	F	V	P	S	A	G	A	D	S	E	T	H	C	

TAA GGGGAGAAAA AAAGCCACTT CTGCTTCTGT GTTTCCAAAC AGCATTGCAT 2260
 *

5	TGATTCAGTA AGATGTTATT TTTGAGGAGT TCCTGGTCCT TTCACTAAGA 2310
	ATTCCACAT CTTTATGGT GGAAGTATAA ATAAGCCTAT GAACTTATAA 2360
	AAAAACAAAC TGTAGGTAGA AAAATGAGA GTACTCATG TTACATTATA 2410
	GCTACATATT TGTGGTTAAG GTTAGACTAT ATGATCCATA CAAATTAAAG 2460
	TGAGAGACAT GGTTACTGTG TAATAAAAGA AAAAATACTT GTTCAGGTAA 2510
10	TTCTAATTCT TAATAAAACA AATGAGTATC ATACAGGTAG AGGTAAAAAA 2560
	GGAGGAGCTA GATTCAATAC CTAAGTAAAG AGAAATGCCT AGTGTCTATT 2610
	TTATTAAACA AACAAACACA GAGTTGAAC TATAACTA AGGCCTGAAG 2660
	TCTAGCTTGG ATATATGCTA CAATAATATC TGTTACTCAC ATAAAATTAT 2710
	ATATTCACA GACTTATCA ATGTATAATT ACAATTATC TTGTTAAGT 2760
15	AAATTTAGAA TACATTTAAG TATTGTGGAA GAAATAAAGA CATTCCAATA 2810
	TTGCAAAAAA AAAAAAAA 2830

OATP-RP2 (SEQ ID NOS:3 and 4):

20	CCCGGGTCGA CCCACCGCGTC CGGGATAAAAG TACTCCCAGG AAGGCTTTGA 50
	GCCTTGGCAG AAGAGGCTGG GATTGAAGCT TCAGGGAGAG CCAGAGGTGA 100
	GGCTGGAGTG GGAGATCACC TGAGGCAGGG CCAGGGGTG AGGTACCCCCA 150
	GGTACCAAGAC AAGGAAACCA AAGCCACA ATG GGC ACA GAA AAC ACA CCT 199
	M G T E N T P
25	GGA GGC AAA GCC AGC CCA GAC CCT CAG GAC GTG CGG CCA AGT 241
	G G K A S P D P Q D V R P S
30	GTG TTC CAT AAC ATC AAG CTG TTC GTT CTG TGC CAC AGC CTG 283
	V F H N I K L F V L C H S L
	CTG CAG CTG GCG CAG CTC ATG ATC TCC GGC TAC CTA AAG AGC 325
	L Q L A Q L M I S G Y L K S
35	TCC ATC TCC ACA GTG GAG AAG CGC TTC GGC CTC TCC AGC CAG 367
	S I S T V E K R F G L S S Q
	ACG TCG GGG CTG CTG GCC TCC TTC AAC GAG GTG GGG AAC ACA 409
	T S G L L A S F N E V G N T
40	GCC TTG ATT GTG TTT GTG AGC TAT TTT GGC AGC CGG GTG CAC 451
	A L I V F V S Y F G S R V H
45	CGA CCC CGA ATG ATT GGC TAT GGG GCT ATC CTT GTG GCC CTG 493
	R P R M I G Y G A I L V A L
	GCG GGC CTG CTC ATG ACT CTC CCG CAC TTC ATC TCG GAG CCA 535
	A G L L M T L P H F I S E P
50	TAC CGC TAC GAC AAC ACC AGC CCT GAG GAT ATG CCA CAG GAC 577
	Y R Y D N T S P E D M P Q D
	TTC AAG GCT TCC CTG TGC CTG CCC ACA ACC TCG GCC CCA GCC 619
	F K A S L C L P T T S A P A
55	TCG GCC CCC TCC AAT GGC AAC TGC TCA AGC TAC ACA GAA ACC 661
	S A P S N G N C S S Y T E T
60	CAG CAT CTG AGT GTG GTG GGG ATC ATG TTC GTG GCA CAG ACC 703
	Q H L S V V G I M F V A Q T
	CTG CTG GGC GTG GGC GGG GTG CCC ATT CAG CCC TTT GGC ATC 745
	L L G V G G V P I Q P F G I
65	TCC TAC ATC GTT GAC TTT GCC CAC AAC AGT AAC TCG CCC CTC 787

DB23(NP)

	S	Y	I	V	D	F	A	H	N	S	N	S	P	L	
	TAC	CTC	GGG	ATC	CTG	TTT	GCA	GTG	ACC	ATG	ATG	GGG	CCA	GGC	829
5	Y	L	G	I	L	F	A	V	T	M	M	G	P	G	
	CTG	GCC	TTT	GGG	CTG	GGC	AGC	CTC	ATG	CTG	CGC	CTT	TAT	GTG	871
10	L	A	F	G	L	G	S	L	M	L	R	L	Y	V	
	GAC	ATT	AAC	CAG	ATG	CCA	GAA	GGT	GGT	ATC	AGC	CTG	ACC	ATA	913
15	D	I	N	Q	M	P	E	G	G	I	S	L	T	I	
	AAG	GAC	CCC	CGA	TGG	G TG	GGT	GCC	TGG	TGG	CTG	GGT	TTC	CTC	955
20	K	D	P	R	W	V	G	A	W	W	L	G	F	L	
	ATC	GCT	GCC	GGT	GCA	GTG	GCC	CTG	GCT	GCC	ATC	CCC	TAC	TTC	997
25	I	A	A	G	A	V	A	L	A	A	I	P	Y	F	
	TTC	TTC	CCC	AAG	GAA	ATG	CCC	AAG	GAA	AAA	CGT	GAG	CTT	CAG	1039
30	F	F	P	K	E	M	P	K	E	K	R	E	L	Q	
	TTT	CGG	CGA	AAG	GTC	TTA	GCA	GTC	ACA	GAC	TCA	CCT	GCC	AGG	1081
35	F	R	R	K	V	L	A	V	T	D	S	P	A	R	
	AAG	GGC	AAG	GAC	TCT	CCC	TCT	AAG	CAG	AGC	CCT	GGG	GAG	TCC	1123
40	K	G	K	D	S	P	S	K	Q	S	P	G	E	S	
	ACG	AAG	AAG	CAG	GAT	GGC	CTA	GTC	CAG	ATT	GCA	CCA	AAC	CTG	1165
45	T	K	K	Q	D	G	L	V	Q	I	A	P	N	L	
	ACT	GTG	ATC	CAG	TTC	ATT	AAA	GTC	TTC	CCC	AGG	GTG	CTG	CTG	1207
50	T	V	I	Q	F	I	K	V	F	P	R	V	L	L	
	CAG	ACC	CTA	CGC	CAC	CCC	ATC	TTC	CTG	CTG	GTG	GTC	CTG	TCC	1249
55	Q	T	L	R	H	P	I	F	L	L	V	V	L	S	
	CAG	GTA	TGC	TTG	TCA	TCC	ATG	GCT	GCG	GGC	ATG	GCC	ACC	TTC	1291
60	Q	V	C	L	S	S	M	A	A	G	M	A	T	F	
	CTG	CCC	AAG	TTC	CTG	GAG	CGC	CAG	TTT	TCC	ATC	ACA	GCC	TCC	1333
65	L	P	K	F	L	E	R	Q	F	S	I	T	A	S	
	TAC	GCC	AAC	CTG	CTC	ATC	GGC	TGC	CTC	TCC	TTC	CCT	TCG	GTC	1375
70	Y	A	N	L	L	I	G	C	L	S	F	P	S	V	
	ATC	GTG	GGC	ATC	GTG	GTG	GGT	GGC	GTC	CTG	GTC	AAG	CGG	CTC	1417
75	I	V	G	I	V	V	G	G	V	L	V	K	R	L	
	CAC	CTG	GGC	CCT	GTG	GGG	TGC	GGT	GCC	CTT	TGC	CTG	CTG	GGG	1459
80	H	L	G	P	V	G	C	G	A	L	C	L	L	G	
	ATG	CTG	CTG	TGC	CTC	TTC	TTC	AGC	CTG	CCG	CTC	TTC	TTT	ATC	1501
85	M	L	L	C	L	F	F	S	L	P	L	F	F	I	
	GGC	TGC	TCC	AGC	CAC	CAG	ATT	GCG	GGC	ATC	ACA	CAC	CAG	ACC	1543
90	G	C	S	S	H	Q	I	A	G	I	T	H	Q	T	
	AGT	GCC	CAC	CCT	GGG	CTG	GAG	CTG	TCT	CCA	AGC	TGC	ATG	GAG	1585
95	S	A	H	P	G	L	E	L	S	P	S	C	M	E	
	GCC	TGC	TCC	TGC	CCA	TTG	GAC	GGC	TTT	AAC	CCT	GTC	TGC	GAC	1627
100	A	C	S	C	P	L	D	G	F	N	P	V	C	D	
	CCC	AGC	ACT	CGT	GTG	GAA	TAC	ATC	ACA	CCC	TGC	CAC	GCA	GGC	1669
105	P	S	T	R	V	E	Y	I	T	P	C	H	A	G	
	TGC	TCA	AGC	TGG	GTG	GTC	CAG	GAT	GCT	CTG	GAC	AAC	AGC	CAG	1711
110	C	S	S	W	V	V	Q	D	A	L	D	N	S	Q	

DB23(NP)

	GTT TTC TAC ACC AAC TGC AGC TGC GTG GTG GAG GGC AAC CCC V F Y T N C S C V V E G N P	1753
5	G TG CTG GCA GGA TCC TGC GAC TCA ACG TGC AGC CAT CTG GTG V L A G S C D S T C S H L V	1795
	G TG CCC TTC CTG CTC CTG GTC AGC CTG GGC TCG GCC CTG GCC V P F L L V S L G S A L A	1837
10	TGT CTC ACC CAC ACA CCC TCC TTC ATG CTC ATC CTA AGA GGA C L T H T P S F M L I L R G	1879
15	G TG AAG AAA GAA GAC AAG ACT TTG GCT GTG GGC ATC CAG TTC V K K E D K T L A V G I Q F	1921
	A TG TTC CTG AGG ATT TTG GCC TGG ATG CCC AGC CCC GTG ATC M F L R I L A W M P S P V I	1963
20	C AC GGC AGC GCC ATC GAC ACC ACC TGT GTG CAC TGG GCC CTG H G S A I D T T C V H W A L	2005
	A GC TGT GGG CGT CGA GCT GTC TGT CGC TAC TAC AAT AAT GAC S C G R R A V C R Y Y N N D	2047
25	C TG CTC CGA AAC CGG TTC ATC GGC CTC CAG TTC TTC TTC AAA L L R N R F I G L Q F F F K	2089
30	A CA GGT TCT GTG ATC TGC TTC GCC TTA GTT TTG GCT GTC CTG T G S V I C F A L V L A V L	2131
	A GG CAG CAG GAC AAA GAG GCA AGG ACC AAA GAG AGC AGA TCC R Q Q D K E A R T K E S R S	2173
35	A GC CCT GCC GTA GAG CAG CAA TTG CTA GTG TCG GGG CCA GGG S P A V E Q Q L L V S G P G	2215
	A AG AAG CCA GAG GAT TCC CGA GTG TGA GCTGTCTTGG GGCCCCACCT K K P E D S R V *	2262
40	GGCCAAGAGT AGCAGGCCACA GCAGTACCTC CTCTGAGTCC TTTGCCAAC ATTGGGTGTC AAGAGCCCTG TGTTCCATTC TGGCTCCTCC ACTAAATTGC TGTGTGACTT CAGGCAAAAA AAAAAAAAAA AAAAAAAAAA AAAAAAAAAA AAAAAAAAAA AAAAAAAAAA AAAAAAAAAA	2312 2362 2412 2442
45		

OATP-RP3 (SEQ ID NOS:5 and 6):

	CC CACGCGTCCG GCGAGGAGCT GTGCCTTCCA CCTCTCCAGC CCCGGCAGGA CGGGGGCGGC 50 CGCCCGCGAAC CGGGGGCGGG GACAGCACCG AGCCTCGAGG CGCGCACCCC CGCCCGGCAG CGGCCCCGAC ACCCGGGGCG AGCAGGGAAAG CGGCAGCGGC GGCGCGCGCG GCAGCGGGCGG GGGAAAGG ATG CAG GGG AAG AAG CCG GGC M Q G K K P G	12 62 112 162 210
55	GGT TCG TCG GGC GGC CGG AGC GGC GAG CTG CAG GGG GAC G S S G G R S G E L Q G D	252
	G AG GCG CAG AGG AAC AAG AAA AAG AAA AAG AAG GTG TCC TGC E A Q R N K K K K K V S C	294
60	TTT TCC AAC ATC AAG ATC TTC CTG GTG TCC GAG TGC GCC CTG F S N I K I F L V S E C A L	336
65	ATG CTG GCG CAG GGC ACG GTG GGC GCC TAC CTG GTG AGC GTC M L A Q G T V G A Y L V S V	378

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	CTG ACC ACC CTG GAG CGT AGG TTC AAC CTG CAG AGC GCT GAC L T T L E R R F N L Q S A D	420
5	G TG GGT GTG ATC GCT AGC AGC TTC GAG ATC GGG AAC CTG GCG V G V I A S S F E I G N L A	462
	CTC ATC CTC TTC GTG AGC TAC TTC GGG GCA CGC GGG CAC CGG L I L F V S Y F G A R G H R	504
10	CCG CGC CTG ATC GGC TGC GGC ATC GTC ATG GCG CTG GGC P R L I G C G G I V M A L G	546
15	GCG CTG CTG TCG GCG CTG CCC GAG TTC CTG ACC CAC CAG TAC A L L S A L P E F L T H Q Y	588
	AAG TAC GAG GCG GGC GAG ATC CGC TGG GGC GCC GAG GGC CGC K Y E A G E I R W G A E G R	630
20	GAC GTC TGC GCA GCC AAC GGC TCG GGC GGC GAC GAG GGG CCC D V C A A N G S G G D E G P	672
	GAC CCC GAC CTC ATC TGC CGC AAC CGG ACG GCT ACC AAC ATG D P D L I C R N R T A T N M	714
25	ATG TAC TTG CTG CTC ATT GGG GCC CAG GTG CTC CTG GGC ATC M Y L L L I G A Q V L L G I	756
30	GGT GCT ACC CCT GTG CAG CCC CTG GGC GTC TCC TAC ATC GAC G A T P V Q P L G V S Y I D	798
	GAC CAC GTG CGG AGG AAG GAC TCC TCG CTC TAT ATA GGA ATC D H V R R K D S S L Y I G I	840
35	CTG TTC ACG ATG CTG GTA TTT GGA CCA GCC TGC GGG TTT ATC L F T M L V F G P A C G F I	882
	CTG GGC TCT TTC TGT ACC AAA ATC TAC GTG GAT GCG GTC TTC L G S F C T K I Y V D A V F	924
40	ATT GAC ACA AGT AAC CTG GAC ATC ACT CCG GAC GAC CCC CGC I D T S N L D I T P D D P R	966
	TGG ATC GGA GCC TGG TGG GGT GGC TTT CTG CTC TGC GGT GCC W I G A W W G G F L L C G A	1008
45	TTA CTC TTC TTC TCT TCC CTC TTG ATG TTT GGG TTT CCA CAG L L F F S S L L M F G F P Q	1050
	TCC CTG CCC CCG CAC TCA GAC CCC GCC ATG GAA AGC GAG CAG S L P P H S D P A M E S E Q	1092
50	GCC ATG CTC TCC GAA AGA GAA TAC GAG AGA CCC AAG CCC AGC A M L S E R E Y E R P K P S	1134
	AAC GGG GTC CTG AGG CAC CCC CTG GAG CCA GAC AGC AGT GCC N G V L R H P L E P D S S A	1176
55	TCC TGT TTC CAG CAG CTG AGA GTG ATC CCG AAG GTC ACC AAG S C F Q Q L R V I P K V T K	1218
	CAC CTG CTC TCA AAC CCT GTG TTC ACC TGC ATC ATC CTG GCC H L L S N P V F T C I I L A	1260
60	GCC TGC ATG GAG ATT GCA GTG GTG GCT GGC TTC GCT GCC TTT A C M E I A V V A G F A A F	1302

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	TTG GGG AAG TAC CTG GAG CAG CAG TTT AAC CTC ACC ACC TCT	1344
	L G K Y L E Q Q F N L T T S	
5	TCT GCC AAC CAG CTG CTT GGG ATG ACT GCG ATC CCG TGT GCT	1386
	S A N Q L L G M T A I P C A	
	TGT CTG GGT ATC TTC CTG GGA GGT CTT TTG GTG AAG AAG CTC	1428
	C L G I F L G G L L V K K L	
10	AGC CTG TCT GCC CTG GGG GCC ATT CGG ATG GCC ATG CTC GTC	1470
	S L S A L G A I R M A M L V	
	AAC CTG GTG TCC ACT GCT TGC TAC GTC TCC TTC CTC TTC CTG	1512
15	N L V S T A C Y V S F L F L	
	GGC TGC GAC ACT GGC CCT GTG GCT GGG GTT ACT GTT CCC TAT	1554
	G C D T G P V A G V T V P Y	
20	GGA AAC AGC ACA GCA CCT GGC TCA GCC CTG GAC CCC TAC TCG	1596
	G N S T A P G S A L D P Y S	
	CCC TGC AAT AAT AAC TGT GAA TGC CAA ACC GAT TCC TTC ACT	1638
	P C N N N C E C Q T D S F T	
25	CCA GTG TGT GGG GCA GAT GGC ATC ACC TAC CTG TCT GCC TGC	1680
	P V C G A D G I T Y L S A C	
	TTT GCT GGC TGC AAC AGC ACG AAT CTC ACG GGC TGT GCG TGC	1722
30	F A G C N S T N L T G C A C	
	CTC ACC ACC GTC CCT GCT GAG AAC GCA ACC GTG GTT CCT GGA	1764
	L T T V P A E N A T V V P G	
35	AAA TGC CCC AGT CCT GGG TGC CAA GAG GCC TTC CTC ACT TTC	1806
	K C P S P G C Q E A F L T F	
	CTC TGT GTG ATG TGT ATC TGC AGC CTG ATC GGT GCC ATG GCA	1848
	L C V M C I C S L I G A M A	
40	CAG ACA CCC TCA GTC ATC ATC CTC ATC AGG ACA GTC AGC CCT	1890
	Q T P S V I I L I R T V S P	
	GAA CTC AAG TCT TAC GCT TTG GGA GTT CTT TTT CTC CTC CTT	1932
45	E L K S Y A L G V L F L L L	
	CGT TTG TTG GGC TTC ATC CCT CCA CCC CTC ATC TTC GGG GCT	1974
	R L L G F I P P L I F G A	
50	GGC ATC GAC TCC ACC TGC CTG TTC TGG AGC ACG TTC TGT GGG	2016
	G I D S T C L F W S T F C G	
	GAG CAA GGC GCC TGC GTC CTC TAC GAC AAT GTG GTC TAC CGA	2058
	E Q G A C V L Y D N V V Y R	
55	TAC CTG TAT GTC AGC ATC GCC ATC GCG CTC AAA TCC TTC GCC	2100
	Y L Y V S I A I A L K S F A	
	TTC ATC CTG TAC ACC ACC ACG TGG CAG TGC CTG AGG AAA AAC	2142
60	F I L Y T T W Q C L R K N	
	TAT AAA CGC TAC ATC AAA AAC CAC GAG GGC GGG CTG AGC ACC	2184
	Y K R Y I K N H E G G L S T	
65	AGT GAG TTC TTT GCC TCT ACT CTG ACC CTA GAC AAC CTG GGG	2226
	S E F F A S T L T L D N L G	
	AGG GAC CCT GTG CCC GCA AAC CAG ACA CAT AGG ACA AAG TTT	2268

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	R	D	P	V	P	A	N	Q	T	H	R	T	K	F	
	ATC	TAT	AAC	CTG	GAA	GAC	CAT	GAG	TGG	TGT	GAA	AAC	ATG	GAG	2310
5	I	Y	N	L	E	D	H	E	W	C	E	N	M	E	
	TCC	GTT	TTA	TAG	TGACTAAAGG	AGGGCTGAAC	TCTGTATTAG	TAATCCAAGG	2362						
5	S	V	L	*											
10	GTCATTTTTT	TCTTAAAAAA	AGAAAAAAAAG	GTTCCAAAAAA	AAACCAAAAC										2412
10	TCAGTACACA	CACACAGGCA	CAGATGCACA	CACACGCAGA	CAGACACACC										2462
	GACTTTGTCC	TTTTTCTCGAG	CATCAGAGCC	AGACAGGATT	CAGAATAAGG										2512
	AGAGAATGAC	ATCGTGCAGC	AGGGTCCTGG	AGGCCACTCG	CGCGGCTGGG										2562
	CCACAGAGTC	TACTTGAAG	GCACCTCATG	GTTCAGGA	TGCTGACAGC										2612
15	TGCAAGCAAC	AGGCAGTGC	AAATTCAAGG	AACAGTGGTG	GCCAGCTTGG										2662
15	AGGATGGACA	TTTCTGGATA	CACATACACA	TACAAAACAG	AAAACATT										2712
	TTAAAAGAAG	TTTCCTAAAAA	TAACCAAGAAG	AAAAAAAGAAG	AAAAAAAGAAG										2757

OATP-RP4 (SEQ ID NOS:7 and 8) (Nucleotide 713, designated Y, can be either a C (in which case the encoded amino acid X is Leu) or a T (in which case the encoded 20 amino acid X is Phe); Nucleotide 2397, designated K, can be either a G (in which case the encoded amino acid X is Gly) or a T (in which case the encoded amino acid X is Val)):

25	CTGATTTCTC	TTCGGCTGGA	CGGAGGCTGC	CTCCTCACGC	GGCTCCCAAC	50									
	TATTCCCGTA	GCTCAGTGC	CCCCTCCCGC	CGCTCTACTC	AGCCAGGCAG	100									
	ACAGACTGAC	AGACTCGCTA	GTCGGCAGCT	TCACTCCCAG	GGGTGCCGCG	150									
	AGCCCAGGCG	CGAACACACC	GGTACCCCTG	CGCAGCGAG	GTGGGATGCT	200									
	GTACGGACAG	CAGCGCTAAG	TGCCCCCCCCA	CCCCCGGCGC	AGGGTGCAC	250									
	CGCTCCTGGC	CGCGGGCCCA	GCGGCGGCGG	CGGCGGCGC	GGCGGAGGGG	300									
30	ATGAGCCCGG	GACGCGCGAG	GCGCCTGCCT	CAAGCTACCG	CCCGGAGAGG	350									
	GACGCCGAGT	AGGGCTCATC	CGAGTACCGC	CGGGACCCCT	GCCCCCTGTG	400									
	GCACGCGGCT	CGGGAGCCTT	GAAGCCGTGT	CTGTGATCAG	GATGCACTGG	450									
	GCGCCTCGCA	GCTGGTGAGG	ATGCCCTGCT	GCGCGGCCCT	GCGCCCCAG	500									
	CCCCAGTCCC	AGGTGGGCAA	GACTGACTGG	GCCCCGCTTC	GGCCCCTCGT	550									
35	GCCGGTGGAT	GAAACGTGCC	GGAGTGCTTG	GGTGCCATCA	GCTATCAAAT	600									
	CTGAATTCTA	AGCGGCC	ATG	GAC	GAA	GGC	ACT	GGA	CTG	CAG	CCC	GGG	646		
	M	D	E	G	T	G	L	Q	P	G					
40	GCG	GGA	GAG	CAG	CTG	GAG	GCG	CCG	GCC	ACT	GCA	GAA	GCT	GTC	688
	A	G	E	Q	L	E	A	P	A	T	A	E	A	V	
	CAA	GAG	AGG	TGC	GAG	CCG	GAG	ACC	YTC	AGG	TCT	AAG	AGT	TTA	730
	Q	E	R	C	E	P	E	T	X	R	S	K	S	L	
45	CCG	GTC	CTC	AGC	AGC	GCC	TCC	TGC	CGG	CCA	AGC	CTC	AGT	CCC	772
	P	V	L	S	S	A	S	C	R	P	S	L	S	P	
	ACT	AGT	GGA	GAC	GCC	AAC	CCG	GCC	TTT	GGC	TGT	GTG	GAT	TCT	814
50	T	S	G	D	A	N	P	A	F	G	C	V	D	S	
	TCG	GGC	CAC	CAG	GAG	TTG	AAG	CAA	GGC	CCG	AAC	CCG	TTG	GCC	856
	S	G	H	Q	E	L	K	Q	G	P	N	P	L	A	
55	CCC	AGT	CCC	TCT	GCC	CCG	TCC	ACT	TCG	GCG	GGG	CTC	GGG	GAC	898
	P	S	P	S	A	P	S	T	S	A	G	L	G	D	
	TGT	AAC	CAC	AGG	GTG	GAC	CTC	AGC	AAA	ACC	TTC	TCG	GTG	TCC	940
	C	N	H	R	V	D	L	S	K	T	F	S	V	S	
60	TCC	GCC	TTG	GCC	ATG	CTC	CAG	GAG	AGA	AGG	TGC	CTC	TAC	GTG	982
	S	A	L	A	M	L	Q	E	R	R	C	L	Y	V	

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	GTC CTC ACG GAT TCC CGT TGC TTC CTG GTG TGC ATG TGC TTT V L T D S R C F L V C M C F	1024
5	CTG ACC TTC ATC CAG GCG TTA ATG GTC TCT GGG TAC CTG AGC L T F I Q A L M V S G Y L S	1066
	AGC GTA ATT ACC ACC ATT GAA AGG CGC TAC AGT CTG AAG AGT S V I T T I E R R Y S L K S	1108
10	TCC GAG TCG GGG CTG CTG GTC AGC TGC TTT GAC ATC GGG AAC S E S G L L V S C F D I G N	1150
15	CTG GTG GTG GTG GTG TTC GTC AGC TAC TTC GGC GGC CGG GGT L V V V V F V S Y F G G R G	1192
	CGG CGG CCC CTG TGG CTG GCC GTG GGT GGA CTC CTC ATC GCC R R P L W L A V G G L L I A	1234
20	TTC GGG GCA GCC CTC TTC GCC TTA CCT CAC TTC ATC TCG CCC F G A A L F A L P H F I S P	1276
	CCC TAC CAG ATC CAA GAG TTG AAC GCC TCG GCC CCC AAC GAC P Y Q I Q E L N A S A P N D	1318
25	GGC CTG TGT CAG GGT GGC AAC TCC ACC GCC ACT TTG GAG CCT G L C Q G G N S T A T L E P	1360
30	CCG GCC TGT CCG AAG GAC TCG GGA GGA AAT AAT CAC TGG GTC P A C P K D S G G N N H W V	1402
	TAC CTG GCT TTA TTC ATT TGC GCG CAG ATT CTC ATT GGA ATG Y L A L F I C A Q I L I G M	1444
35	GGC TCC ACA CCT ATT TAT ACC CTG GGA CCA ACC TAC TTA GAT G S T P I Y T L G P T Y L D	1486
	GAC AAT GTC AAG AAA GAA AAC TCC TCC TTG TAC CTA GCC ATC D N V K K E N S S L Y L A I	1528
40	ATG TAT GTC ATG GGA GCA CTT GGC CCT GCA GTG GGA TAT TTA M Y V M G A L G P A V G Y L	1570
	TTA GGT GGA CTT CTT ATT GGT TTT TAT GTT GAT CCC AGA AAT L G G L L I G F Y V D P R N	1612
45	CCT GTT CAC CTT GAC CAG AAT GAC CCT CGT TTC ATT GGA AAC P V H L D Q N D P R F I G N	1654
	TGG TGG AGT GGA TTC CTC CTT TGT GCC ATT GCA ATG TTT CTT W W S G F L L C A I A M F L	1696
50	GTG ATA TTC CCA ATG TTT ACT TTC CCA AAA AAG CTT CCA CCT V I F P M F T F P K K L P P	1738
	CGA CAC AAG AAA AAG AAA AAG AAA AAA TTT TCT GTT GAT GCT R H K K K K K F S V D A	1780
55	GTT AGT GAT GAC GAT GTT CTG AAG GAG AAA TCA AAC AAC AGT V S D D D V L K E K S N N S	1822
	GAA CAA GCG GAC AAA AAA GTT TCT TCG ATG GGA TTT GGA AAG E Q A D K K V S S M G F G K	1864
60	GAT GTC AGA GAC CTA CCA AGA GCA GCT GTC AGG ATC TTA AGC D V R D L P R A A V R I L S	1906

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	F	G	L	A	A	G	L	K	F	V	G	F	I	F	
	ATT	TTT	CTG	GCC	TGG	TAC	TCC	ATA	AAA	TAC	AAG	GAG	GAT	GGA	2914
5	I	F	L	A	W	Y	S	I	K	Y	K	E	D	G	
	CTG	CAG	AGG	CGG	AGG	CAG	AGA	GAA	TTT	CCC	CTG	AGC	ACC	GTG	2956
	L	Q	R	R	R	Q	R	E	F	P	L	S	T	V	
10	AGT	GAG	AGA	GTG	GGA	CAC	CCC	GAC	AAT	GCC	CGG	ACT	AGA	TCT	2998
	S	E	R	V	G	H	P	D	N	A	R	T	R	S	
	TGC	CCA	GCT	TTC	AGC	ACC	CAG	GGA	GAA	TTC	CAC	GAA	GAG	ACT	3040
	C	P	A	F	S	T	Q	G	E	F	H	E	E	T	
15	GGC	CTG	CAA	AAA	GGG	ATC	CAG	TGC	GCA	GCA	CAG	ACC	TAC	CCG	3082
	G	L	Q	K	G	I	Q	C	A	A	Q	T	Y	P	
	GGG	CCC	TTC	CCA	GAA	GCA	ATA	AGT	TCC	TCT	GCG	GAC	CCG	GGG	3124
20	G	P	F	P	E	A	I	S	S	S	A	D	P	G	
	CTG	GAA	GAG	AGC	CCC	GCT	GCC	TTG	GAG	CCG	CCC	TCC	TGA		3163
	L	E	E	S	P	A	A	L	E	P	P	S	*		
25	AGCTTGAAAA	TGGAAGAATT	TAGTTTTGTT	GGTTGAATTG	AAAATGGCGA										3213
	CTTGAGAAC	AACTGTGCCT	TCTTTCTTT	CTTTCTTTT	TTTAACCTCT										3263
	ACAGACACAA	TCCTCAAACC	AACAAAACTC	AGTATACACA	GCCGCTATT										3313
	ATTGAGGGCT	GGATACCTCA	ACAAGACTGA	GAGCCTTCC	CCGCTTCTCT										3363
	CCAAGAAGGA	GACGTTCAGC	TAGATTGTT	CCCATTCCG	TTGTGTTAAT										3413
30	TCAAAGCTCA	TGCTCCCCTA	CGGTACAGGC	TGAGGTACAC	GGTTAGCAAA										3463
	ACCATGGAA	GGGAATGGC	GGTGCATATC	ATTAACTAAC	ACTCCAAACA										3513
	AAGGTGAGCT	TGCC CAGGAC	TTGGCATTTC	CAAATCAAAG	TTTTTAGATA										3563
	TGAACACCTA	CTGTGAGTTC	TGCTACAAAG	CACAAATGAA	TTTGTCCTCAA										3613
	CTATGCAATT	TGATTGGAAA	AATGTATGTG	CAGCATGTTA	CATTTACTTT										3663
	CACCGAATAA	AGCAGATATG	TTTCTGAAA												3692
35															
	OATP-RP5 (SEQ ID NOS:9 and 10):														
	CGCAAAGAAA	TGGCTAAAAA	GCTTCAGCTC	TTTCTGTGCC	CTGGGAGCTG										50
40	AGATGCACT	CAGTGGCCTT	GCCAGCGTGG	CCAATTCTCT	GCTGACTGCC										100
	AGAAAAAAAGA	GGCCAGGAAG	AAAGAGGAAA	GAGAAGAGAT	CGCTCAGGGG										150
	TGAGACCATG	CCCTTCATCT	TTTCTTTCC	CTAATCTCCT	CTGCTTGTGT										200
	CCACCCACAC	TCTCCCCACC	TGGCAAAATT	GTCAAAATT	GCTGTGGAGT										250
	TTACCTCAGT	TTCCTCTTC	AGTCTGTGGT	GTGTGGTCCA	TCCTCTTGCT										300
	GAGCACATTG	AAAGGAACTG	GCTATCTTG	ATCTCTTCCT	CCAGATCAGA										350
45	GTCAAGGAAT	GTGTTATA	ATG GAC ACT	TCA TCC AAA	GAA AAT ATC										396
	M	D	T	S	S	K	E	N	I						
	CAG	TTG	TTC	TGC	AAA	ACT	TCA	GTG	CAA	CCT	GTT	GGA	AGG	CCT	438
50	Q	L	F	C	K	T	S	V	Q	P	V	G	R	P	
	TCT	TTT	AAA	ACA	GAA	TAT	CCC	TCC	TCA	GAA	GAA	AAG	CAA	CCA	480
	S	F	K	T	E	Y	P	S	S	E	E	K	Q	P	
	TGC	TGT	GGT	GAA	CTA	AAG	GTG	TTC	TTG	TGT	GCC	TTG	TCT	TTT	522
55	C	C	G	E	L	K	V	F	L	C	A	L	S	F	
	GTT	TAC	TTT	GCC	AAA	GCA	TTG	GCA	GAA	GGC	TAT	CTG	AAG	AGC	564
	V	Y	F	A	K	A	L	A	E	G	Y	L	K	S	
60	ACC	ATC	ACT	CAG	ATA	GAG	AGA	AGG	TTT	GAT	ATC	CCT	TCT	TCA	606
	T	I	T	Q	I	E	R	R	F	D	I	P	S	S	
	CTG	GTG	GGA	GTT	ATT	GAT	GGT	AGT	TTT	GAA	ATT	GGG	AAT	CTC	648
65	L	V	G	V	I	D	G	S	F	E	I	G	N	L	

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	TTA GTT ATA ACA TTT GTT AGC TAC TTT GGA GCC AAA CTT CAC L V I T F V S Y F G A K L H	690
5	AGG CCA AAA ATA ATT GGA GCA GGG TGT GTA ATC ATG GGA GTT R P K I I G A G C V I M G V	732
	GGA ACA CTG CTC ATT GCA ATG CCT CAG TTC TTC ATG GAG CAG G T L L I A M P Q F F M E Q	774
10	TAC AAA TAT GAG AGA TAT TCT CCT TCC TCC AAT TCC ACT CTC Y K Y E R Y S P S S N S T L	816
15	AGC ATC TCT CCG TGT CTC CTA GAG TCA AGC AGT CAA TTA CCA S I S P C L L E S S S Q L P	858
	GTT TCA GTT ATG GAA AAA TCA AAA TCC AAA ATA AGT AAC GAA V S V M E K S K S K I S N E	900
20	TGT GAA GTG GAC ACT AGC TCT TCC ATG TGG ATT TAT GTT TTC C E V D T S S S M W I Y V F	942
	CTG GGC AAT CTT CTT CGT GGA ATA GGA GAA ACT CCC ATT CAG L G N L L R G I G E T P I Q	984
25	CCT TTG GGC ATT GCC TAC CTG GAT GAT TTT GCC AGT GAA GAC P L G I A Y L D D F A S E D	1026
30	AAT GCA GCT TTC TAT ATT GGG TGT GTG CAG ACG GTT GCA ATT N A A F Y I G C V Q T V A I	1068
	ATA GGA CCA ATC TTT GGT TTC CTG TTA GGC TCA TTA TGT GCC I G P I F G F L L G S L C A	1110
35	AAA CTA TAT GTT GAC ATT GGC TTT GTA AAC CTA GAT CAC ATA K L Y V D I G F V N L D H I	1152
	ACC ATT ACC CCA AAA GAT CCC CAG TGG GTA GGA GCC TGG TGG T I T P K D P Q W V G A W W	1194
40	CTT GGC TAT CTA ATA GCA GGA ATC ATA AGT CTT CTT GCA GCT L G Y L I A G I I S L L A A	1236
45	GTG CCT TTC TGG TAT TTA CCA AAG AGT TTA CCA AGA TCC CAA V P F W Y L P K S L P R S Q	1278
	AGT AGA GAG GAT TCT AAT TCT TCC TCT GAG AAA TCC AAG TTT S R E D S N S S E K S K F	1320
50	ATT ATA GAT GAT CAC ACA GAC TAC CAA ACA CCC CAG GGA GAA I I D D H T D Y Q T P Q G E	1362
	AAT GCA AAA ATA ATG GAA ATG GCA AGA GAT TTT CTT CCA TCA N A K I M E M A R D F L P S	1404
55	CTG AAG AAT CTT TTT GGA AAC CCA GTA TAC TTC CTA TAT TTA L K N L F G N P V Y F L Y L	1446
	TGT ACA AGC ACT GTT CAG TTC AAT TCT CTG TTC GGC ATG GTG C T S T V Q F N S L F G M V	1488
60	ACG TAC AAA CCA AAG TAC ATT GAG CAG CAG TAT GGA CAG TCA T Y K P K Y I E Q Q Y G Q S	1530
65	TCC TCC AGG GCC AAC TTT GTG ATC GGG CTC ATC AAC ATT CCA S S R A N F V I G L I N I P	1572
	GCA GTG GCC CTT GGA ATA TTC TCT GGG GGG ATA GTT ATG AAA	1614

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	A	V	A	L	G	I	F	S	G	G	I	V	M	K	
	AAA	TTC	AGA	ATC	AGT	GTG	TGT	GGA	GCT	GCA	AAA	CTC	TAC	TTG	1656
5	K	F	R	I	S	V	C	G	A	A	K	L	Y	L	
	GGA	TCA	TCT	GTC	TTT	GGT	TAC	CTC	CTA	TTT	CTT	TCC	CTG	TTT	1698
	G	S	S	V	F	G	Y	L	L	F	L	S	L	F	
10	GCA	CTG	GGC	TGT	GAA	AAT	TCT	GAT	GTG	GCA	GGA	CTA	ACT	GTC	1740
	A	L	G	C	E	N	S	D	V	A	G	L	T	V	
	TCC	TAC	CAA	GGA	ACC	AAA	CCT	GTC	TCT	TAT	CAT	GAA	CGA	GCT	1782
15	S	Y	Q	G	T	K	P	V	S	Y	H	E	R	A	
	CTC	TTT	TCA	GAT	TGC	AAC	TCA	AGA	TGC	AAA	TGT	TCA	GAG	ACA	1824
	L	F	S	D	C	N	S	R	C	K	C	S	E	T	
20	AAA	TGG	GAA	CCC	ATG	TGC	GGT	GAA	AAT	GGA	ATC	ACA	TAT	GTA	1866
	K	W	E	P	M	C	G	E	N	G	I	T	Y	V	
	TCA	GCT	TGT	CTT	GCT	GGT	TGT	CAA	ACC	TCC	AAC	AGG	AGT	GGA	1908
	S	A	C	L	A	G	C	Q	T	S	N	R	S	G	
25	AAA	AAT	ATT	ATA	TTT	TAC	AAC	TGC	ACT	TGT	GTG	GGA	ATT	GCA	1950
	K	N	I	I	F	Y	N	C	T	C	V	G	I	A	
	GCT	TCT	AAA	TCC	GGA	AAT	TCC	TCA	GGC	ATA	GTG	GGA	AGA	TGT	1992
30	A	S	K	S	G	N	S	S	G	I	V	G	R	C	
	CAG	AAA	GAC	AAT	GGA	TGT	CCC	CAA	ATG	TTT	CTG	TAT	TTC	CTT	2034
	Q	K	D	N	G	C	P	Q	M	F	L	Y	F	L	
35	GTA	ATT	TCA	GTC	ATC	ACA	TCC	TAT	ACT	TTA	TCC	CTA	GGT	GGC	2076
	V	I	S	V	I	T	S	Y	T	L	S	L	G	G	
	ATA	CCT	GGA	TAC	ATA	TTA	CTT	CTG	AGG	TGC	ATT	AAG	CCA	CAG	2118
	I	P	G	Y	I	L	L	R	C	I	K	P	Q		
40	CTT	AAG	TCT	TTT	GCC	TTG	GGT	ATC	TAC	ACA	TTA	GCA	ATA	AGA	2160
	L	K	S	F	A	L	G	I	Y	T	L	A	I	R	
	GTT	CTT	GCA	GGA	ATC	CCA	GCT	CCA	GTG	TAT	TTT	GGA	GTT	TTG	2202
45	V	L	A	G	I	P	A	P	V	Y	F	G	V	L	
	ATT	GAT	ACT	TCA	TGC	CTC	AAA	TGG	GGA	TTT	AAA	AGA	TGT	GGA	2244
	I	D	T	S	C	L	K	W	G	F	K	R	C	G	
50	AGT	AGA	GGA	TCA	TGC	AGA	TTA	TAT	GAT	TCA	AAT	GTC	TTC	AGA	2286
	S	R	G	S	C	R	L	Y	D	S	N	V	F	R	
	CAT	ATA	TAT	TTG	GGA	CTA	ACT	GTG	ATA	CTG	GGC	ACA	GTG	TCA	2328
	H	I	Y	L	G	L	T	V	I	L	G	T	V	S	
55	ATT	CTC	CTA	AGC	ATT	GCA	GTA	CTT	TTC	ATT	TTA	AAG	AAA	AAT	2370
	I	L	L	S	I	A	V	L	F	I	L	K	K	N	
	TAT	GTT	TCA	AAA	CAC	AGA	AGT	TTT	ATA	ACC	AAG	AGA	GAA	AGA	2412
60	Y	V	S	K	H	R	S	F	I	T	K	R	E	R	
	ACA	ATG	GTG	TCT	ACA	AGA	TTC	CAA	AAG	GAA	AAT	TAC	ACT	ACA	2454
	T	M	V	S	T	R	F	Q	K	E	N	Y	T	T	
65	AGT	GAT	CAT	CTG	CTA	CAA	CCC	AAC	TAC	TGG	CCA	GGC	AAG	GAA	2496
	S	D	H	L	L	Q	P	N	Y	W	P	G	K	E	
	ACT	CAA	CTT	TAG	AAACATGATG	ACTGGAGTC	ATGTCTCTA								2538

DB23(NP)

	T	Q	L	*	
	ATTGGTTGAC	ATTTGCAAA	CAAATAAATT	GTAATCAAAA	GAGCTCTAAA
	TTTGTAAATT	CTTTCTCCTT	TCAAAAAATG	TCTACTTTGT	TTTGGTCCTA
5	GGCATTAGGT	AATATAACTG	ATAATATACT	GAAATATATA	ATGGAAGATG
	CAGATGATAA	AACTAATT	GAACCTTTA	ATTTATATAA	ATTATTTAT
	ATCATTTACT	TATTTCACTT	TATTTGCCTT	TGTGCTCATT	GATATATATT
	AGCTGTACTC	CTAGAAGAAC	AATTGTCTCT	ATTGTCACAC	ATGGTTATAT
	TTAAAGTAAT	TTCTGAAC	TGTAATGTGT	CTAGAGTAAG	CAAATACTGC
10	TAACAATTAA	CTCATACCTT	GGGTTCCCTC	AAGTATTACT	CCTATAGTAT
	TTTCTCCC	CAT AGCTGTCTTC	ATCTGTGTAT	TTTAATAATG	ATCTTAGGAT
	GGAGCAGAAC	ATGGAGAGGA	AGATTTCATT	TTAAGCTCCT	CCTTTCC
	GAAATACAAT	AATTATATA	GAAATGTGTA	GCAGCAAATT	ATATTGGGGA
	TTAGAATT	TT GAATTAATAG	CTCTCCTACT	ATTAATTTAC	ATGTGCTTT
15	TGTGTGGCGC	TATAAGTGAC	TATGGTTGTA	AAGTAATAAA	ATTGATGTTA
	ACATGCCAA	TTATTGTTCT	TTTATGAATT	CAATGAATT	AAAACTATTG
	TTAAATATAA	TA C T G C C C A	CTTAATATA	TGTAAGCAAC	TTCCTACTTA
	TACACGACGT	GTTCTAA	AAA CATGTTGAA	AGGTGAATT	CTGAAAGTCT
	CCCATAATG	TAGGTGTTAC	AACAGGAAAA	AAAAAAAAAA	AAA
20					3381

DB23(NP)

OATP-RP1 (SEQ ID NOS:11 and 12):

	GGCACGAG	GCGCTGCAGC	18
	GCGCGGCCGC	CGGGCCCTCG	68
	AGACGGGGAC	GGACACACCA	
	TACCACTTGG	GCCCCTCGGA	118
5	CCACTCCCGC	TGAGGCCACT	
	TCGAGGTACAC	CCCACACTGGT	166
	CAGGCGGAGG	GGCTGAAGCC	
	CGCGGAG	ATG CCC CTG CAT CAG CTG GGG	
	M P L H Q L G		
	GAC AAG CCG CTC ACC TTC CCC AGC CCC AAC TCA GCC ATG GAA		208
10	D K P L T F P S P N S A M E		
	AAC GGG CTT GAC CAC ACC CCA CCC AGC AGG AGG GCA TCC CCG		250
	N G L D H T P P S R R A S P		
15	GGC ACA CCC CTG AGC CCC GGG TCC CTC CGC TCC GCT GCC CAT		292
	G T P L S P G S L R S A A H		
	AGC CCC CTG GAC ACC AGC AAG CAG CCC CTC TGC CAG CTC TGG		334
	S P L D T S K Q P L C Q L W		
20	GCC GAG AAG CAT GGC GCC CGG GGG ACC CAT GAG GTG CGG TAC		376
	A E K H G A R G T H E V R Y		
	GTC TCG GCC GGG CAG AGC GTG GCG TGC GGC TGG TGG GCC TTC		418
25	V S A G Q S V A C G W W A F		
	GCA CCG CCG TGC CTG CAG GTC CTC AAC ACG CCC AAG GGC ATC		460
	A P P C L Q V L N T P K G I		
30	CTG TTC CTG TGT GCG GCC GCA TTC CTG CAG GGG ATG ACT		502
	L F F L C A A A F L Q G M T		
	GTG AAT GGC TTC ATC AAC ACA GTC ATC ACC TCC CTG GAG CGC		544
	V N G F I N T V I T S L E R		
35	CGC TAT GAC CTG CAC AGC TAC CAG AGC GGG CTC ATC GCC AGC		586
	R Y D L H S Y Q S G L I A S		
	TCC TAC GAC ATT GCC GCC TGC CTC TGC CTC ACC TTC GTC AGC		628
40	S Y D I A A C L C L T F V S		
	TAC TTC GGG GGC TCA GGG CAC AAG CCG CGC TGG CTG GGC TGG		670
	Y F G G S G H K P R W L G W		
45	GGC GTG CTG CTT ATG GGC ACG GGG TCG CTG GTG TTC GCG CTG		712
	G V L L M G T G S L V F A L		
	CCC CAC TTC ACG GCT GGC CGC TAT GAG GTG GAG TTG GAC GCG		754
50	P H F T A G R Y E V E L D A		
	GGT GTC AGG ACG TGC CCT GCC AAC CCC GGC GCG GTG TGT GCG		796
	G V R T C P A N P G A V C A		
55	GAC AGC ACC TCG GGC CTG TCC CGC TAC CAG CTG GTC TTC ATG		838
	D S T S G L S R Y Q L V F M		
	CTG GGC CAG TTC CTG CAT GGC GTG GGT GCC ACA CCC CTC TAC		880
60	L G Q F L H G V G A T P L Y		
	ACG CTG GGC GTC ACC TAC CTG GAT GAG AAC GTC AAG TCC AGC		922
	T L G V T Y L D E N V K S S		
	TGC TCG CCC GTC TAC ATT GCC ATC TTC TAC ACA GCG GCC ATC		964
65	C S P V Y I A I F Y T A A I		
	CTG GGC CCA GCT GCC GGC TAC CTG ATT GGA GGT GCC CTG CTG		1006

DB23(NP)

	L	G	P	A	A	G	Y	L	I	G	G	A	L	L	
	AAT	ATC	TAC	ACG	GAA	ATG	GGC	CGA	CGG	ACG	GAG	CTG	ACC	ACC	1048
5	N	I	Y	T	E	M	G	R	R	T	E	L	T	T	
	GAG	AGC	CCA	CTG	TGG	GTC	GGC	GCC	TGG	TGG	GTC	GGC	TTC	CTG	1090
	E	S	P	L	W	V	G	A	W	W	V	G	F	L	
10	GGC	TCT	GGG	GCC	GCT	GCT	TTC	TTC	ACC	GCC	GTT	CCC	ATC	CTT	1132
	G	S	G	A	A	A	F	F	T	A	V	P	I	L	
	GGT	TAC	CCT	CGG	CAG	CTG	CCA	GGC	TCC	CAG	CGC	TAC	GCG	GTC	1174
	G	Y	P	R	Q	L	P	G	S	Q	R	Y	A	V	
15	ATG	AGA	GCG	GCG	GAA	ATG	CAC	CAG	TTG	AAG	GAC	AGC	AGC	CGT	1216
	M	R	A	A	E	M	H	Q	L	K	D	S	S	R	
	GGG	GAG	GCG	AGC	AAC	CCG	GAC	TTT	GGG	AAA	ACC	ATC	AGA	GAC	1258
20	G	E	A	S	N	P	D	F	G	K	T	I	R	D	
	CTG	CCT	CTC	TCC	ATC	TGG	CTC	CTG	CTG	AAG	AAC	CCC	ACG	TTC	1300
	L	P	L	S	I	W	L	L	L	K	N	P	T	F	
25	ATC	CTG	CTC	TGC	CTG	GCC	GGG	GCC	ACC	GAG	GCC	ACT	CTC	ATC	1342
	I	L	L	C	L	A	G	A	T	E	A	T	L	I	
	ACC	GGC	ATG	TCC	ACG	TTC	AGC	CCC	AAG	TTC	TTG	GAG	TCC	CAG	1384
	T	G	M	S	T	F	S	P	K	F	L	E	S	Q	
30	TTC	AGC	CTG	AGT	GCC	TCA	GAA	GCT	GCC	ACC	TTG	TTT	GGG	TAC	1426
	F	S	L	S	A	S	E	A	A	T	L	F	G	Y	
	CTG	GTG	GTG	CCA	GCG	GGT	GGT	GGC	GGC	ACC	TTC	CTG	GGC	GGC	1468
35	L	V	V	P	A	G	G	G	G	T	F	L	G	G	
	TTC	TTT	GTG	AAC	AAG	CTC	AGG	CTC	CGG	GGC	TCC	GCG	GTC	ATC	1510
	F	F	V	N	K	L	R	L	R	G	S	A	V	I	
40	AAG	TTC	TGC	CTG	TTC	TGC	ACC	GTT	GTC	AGC	CTG	CTG	GGC	ATC	1552
	K	F	C	L	F	C	T	V	V	S	L	L	G	I	
	CTC	GTC	TTC	TCA	CTG	CAC	TGC	CCC	AGT	GTG	CCC	ATG	GCG	GGC	1594
	L	V	F	S	L	H	C	P	S	V	P	M	A	G	
45	GTC	ACA	GCC	AGC	TAC	GGC	GGG	AGC	CTC	CTG	CCC	GAA	GGC	CAC	1636
	V	T	A	S	Y	G	G	S	L	L	P	E	G	H	
	CTG	AAC	CTA	ACG	GCT	CCC	TGC	AAC	GCT	GCC	TGC	AGC	TGC	CAG	1678
50	L	N	L	T	A	P	C	N	A	A	C	S	C	Q	
	CCA	GAA	CAC	TAC	AGC	CCT	GTG	TGC	GGC	TCG	GAC	GGC	CTC	ATG	1720
	P	E	H	Y	S	P	V	C	G	S	D	G	L	M	
55	TAC	TTC	TCA	CTG	TGC	CAC	GCA	GGG	TGC	CCT	GCA	GCC	ACG	GAG	1762
	Y	F	S	L	C	H	A	G	C	P	A	A	T	E	
	ACG	AAT	GTG	GAC	GGC	CAG	AAG	GTG	TAC	CGA	GAC	TGT	AGC	TGT	1804
60	T	N	V	D	G	Q	K	V	Y	R	D	C	S	C	
	ATC	CCT	CAG	AAT	CTT	TCC	TCT	GGT	TTT	GGC	CAT	GCC	ACT	GCA	1846
	I	P	Q	N	L	S	S	G	F	G	H	A	T	A	
	GGG	AAA	TGC	ACT	TCA	ACT	TGT	CAG	AGA	AAG	CCC	CTC	CTT	CTG	1888
65	G	K	C	T	S	T	C	Q	R	K	P	L	L	L	
	GTT	TTC	ATA	TTC	GTT	GTA	ATT	TTC	TTT	ACA	TTC	CTC	AGC	AGC	1930
	V	F	I	F	V	V	I	F	F	T	F	L	S	S	

	ATT CCT GCA CTA ACG GCA ACT CTA CGA TGT GTC CGT GAC CCT	1972
	I P A L T A T L R C V R D P	
5	CAG AGA TCC TTT GCC CTG GGA ATC CAG TGG ATT GTA GTT AGA	2014
	Q R S F A L G I Q W I V V R	
10	ATA CTA GGG GGC ATC CCG GGG CCC ATC GCC TTC GGC TGG GTG	2056
	I L G G I P G P I A F G W V	
10	ATC GAC AAG GCC TGT CTG CTG TGG CAG GAC CAG TGT GGC CAG	2098
	I D K A C L L W Q D Q C G Q	
15	CAG GGC TCC TGC TTG GTG TAC CAG AAT TCG GCC ATG AGC CGC	2140
	Q G S C L V Y Q N S A M S R	
	TAC ATA CTC ATC ATG GGG CTC CTG TAC AAG GTG CTG GGC GTC	2182
	Y I L I M G L L Y K V L G V	
20	CTC TTC TTT GCC ATA GCC TGC TTC TTA TAC AAG CCC CTG TCG	2224
	L F F A I A C F L Y K P L S	
	GAG TCT TCA GAT GGC CTG GAA ACT TGT CTG CCC AGC CAG TCC	2266
	E S S D G L E T C L P S Q S	
25	TCA GCC CCT GAC AGT GCC ACA GAT AGC CAG CTC CAG AGC AGC	2308
	S A P D S A T D S Q L Q S S	
30	GTC TGA CCACCGCCCCG CGCCCCACCCCG GCCACGGCGG GCACTCAGCA	2354
	V *	
	TTTCCTGATG ACAGAACAGT GCCGTTGGGT GATGCAATCA CACGGGAACT	2404
	TCTATTTGAC CTGCAACCTT CTACTTAACC TGTGTTTAA AGTCGGCTGT	2454
35	GACCTCCTGT CCCCAGAGCT GTACGGCCCT GCAGTGGGTG GGAGGAACCT	2504
	GCATAAATAT ATATTTATGG ACACACAGGT TGATCATCAGAA CGTGTTTATA	2554
	GAATGTGTTT TATACCCGAT CGTGTGTGGT GTGCGTGAGG ACAAAACTCCG	2604
	CAGGGGCTGT GAATCCCCT GGGAGGGCGG CGGGCCTGCA GCCCCGAGGAA	2654
	GGCTTGTGTG TCCTCAGTTA AAACCTGTGCA TATCGAAATA TATTTTGTAA	2704
40	TTTAAGCCTG CGAAAAAAA AAAAAAAA AAAAAAAA AAAAAAAA AAAAAAAA	2754
	AAAAAAAAAA	2763

Persons skilled in the art can also modify the nucleic acids coding for the OATPs of the present invention to prepare useful mutations. For example, one may 45 modify the sequence to provide additional restriction endonuclease recognition sites in the nucleic acid. Such mutations may be silent or may change the amino acid encoded by the mutated codon. One can prepare these modified nucleic acids, for example, by mutating the nucleic acid coding for an OATP of the present invention to result in deletion, substitution, insertion, inversion or addition of one or more amino acids in the encoded polypeptide. For methods of site-directed mutagenesis, see 50 Taylor, J. W. et al. (1985), Nucl. Acids Res. 13, 8749-64 and Kunkel, J. A. (1985), Proc. Natl. Acad. Sci. USA 82: 482-92. In addition, kits for site-directed mutagenesis are available from commercial vendors (e.g., BioRad Laboratories, Richmond, CA;

Amersham Corp., Arlington Heights, IL). For disruption, deletion and truncation methods, see Sayers, J. R. et al. (1988), Nucl. Acids Res. 16: 791-800.

This invention also comprises modified nucleic acids, including (1) alternative splice exon variants; (2) allelic variants; and (3) chimeric proteins in which the fusion 5 construct comprises an OATP or fragment thereof. Such modified nucleic acids can be obtained by persons of ordinary skill in the art when armed with the present disclosure.

Expression vectors

This invention further concerns expression vectors comprising a nucleotide 10 sequence encoding an OATP of the present invention. Preferably, the expression vectors comprise all or a portion of the nucleic acid sequence as shown in SEQ ID NO:1, SEQ ID NO:3, SEQ ID NO:5, SEQ ID NO:7, SEQ ID NO:9, or SEQ ID NO:11; preferred is a nucleotide sequence encoding an OATP as shown above (i.e., the coding region).

15 Expression vectors are usually plasmids, but the invention includes other vector forms that serve equivalent functions and become known in the art subsequently hereto. A person skilled in the art might also stably integrate a sequence encoding an OATP into the chromosome of an appropriate host cell.

20 Expression vectors typically contain regulatory elements capable of affecting expression of an OATP. These regulatory elements can be heterologous or native OATP elements. Typically, a vector contains an origin of replication, a promoter, and a transcription termination sequence. The vector may also include other regulatory sequences, including mRNA stability sequences, which provide for stability of the expression product; secretory leader sequences, which provide for secretion of the 25 expression product; environmental feedback sequences, which allow expression of the structural gene to be modulated (e.g., by the presence or absence of nutrients or other inducers in the growth medium); marking sequences, which are capable of providing phenotypic selection in transformed host cells; restriction sites, which provide sites for cleavage by restriction endonucleases; and sequences which allow expression in 30 various types of hosts, including prokaryotes, yeasts, fungi, plants and higher eukaryotes.

An expression vector of this invention is at least capable of directing the replication, and preferably the expression, of the nucleic acids and protein of this invention. Suitable origins of replication include, for example, the Col E1, the SV40 viral, Epstein Barr viral, and the M13 origins of replication. Suitable promoters 5 include, for example, the cytomegalovirus promoter, the lacZ promoter, the gal10 promoter and the Autographa californica multiple nuclear polyhedrosis virus (AcMNPV) polyhedral promoter. Suitable termination sequences include, for example, the bovine growth hormone, SV40, lacZ and AcMNPV polyhedral polyadenylation signals. Examples of selectable markers include neomycin, 10 ampicillin, and hygromycin resistance and the like.

Persons skilled in the art may insert DNA encoding An OATP of the present invention into several commercially available vectors. Examples include vectors compatible with mammalian cells, such as pcDNA3 or pCEP4; baculovirus vectors such as pBlueBac; prokaryotic vectors such as pcDNA2; and yeast vectors such as 15 pYes2. For vector modification techniques, see Sambrook *et al.* (1989), Molecular Cloning: A Laboratory Manual, Second Edition, Cold Spring Harbor Laboratory, Cold Spring Harbor, NY.

Host cells

This invention additionally concerns host cells containing an expression vector 20 that comprises a sequence encoding an OATP, preferably the OATP2, OATP-RP2, OATP-RP3, OATP-RP4, OATP-RP5 or OATP-RP1 of the present invention. The host cells preferably contain an expression vector which comprises all or part of the DNA sequence having the nucleotide sequence substantially as shown in SEQ ID NO:1, SEQ ID NO:3, SEQ ID NO:5, SEQ ID NO:7, SEQ ID NO:9, or SEQ ID 25 NO:11, particularly the coding regions thereof. Suitable host cells include both prokaryotic cells (e.g., E. coli strains HB101, DH5a, XL1 Blue, Y1090 and JM101) and eukaryotic cells (e.g., Spodoptera frugiperda insect cells, CHO cells, COS-7 cells, HEK 293 cells, human skin fibroblasts, and S. cerevisiae cells).

Persons skilled in the art may introduce expression vectors into host cells by 30 various methods known in the art. Exemplary methods are transfection by calcium phosphate precipitation, electroporation, liposomal fusion, nuclear injection, and viral

or phage infection. One may then culture the host cell under conditions permitting expression of large amounts of OATP.

One may identify such modified host cells by any of five general approaches:

- (a) DNA-DNA hybridization with probes complementary to the sequence 5 encoding an OATP (Southern blotting).
- (b) detection of marker gene functions, such as thymidine kinase activity, resistance to antibiotics, and the like. A marker gene can be placed in the same plasmid as an OATP sequence under the regulation of the same or a different promoter.
- 10 (c) detection of mRNA transcripts by hybridization assays (e.g., Northern blotting or a nuclease protection assay using a probe complementary to the RNA sequence).
- (d) immunodetection of gene expression (e.g., by Western blotting with antibody to OATP).
- 15 (e) PCR with primers homologous to expression vector sequences or sequences encoding OATP. The PCR produces a DNA fragment of predicted length, indicating incorporation of the expression system in the host cell.

Persons skilled in the art may determine DNA sequences by various known methods. See, for example, the dideoxy chain termination method in Sanger *et al.* 20 (1977), Proc. Natl. Acad. Sci. USA 74: 5463-7 and the Maxam-Gilbert method in Maxam-Gilbert (1977), Proc. Natl. Acad. Sci. USA 74: 560-4.

One may use the host cells of this invention in a variety of ways that are now apparent. One may use the cells to screen for compounds that bind to or otherwise modulate or regulate the function of an OATP of the present invention, which would 25 be useful for modulation, for example activation or inactivation, of OATP2, OATP-RP2, OATP-RP3, OATP-RP4, OATP-RP5 or OATP-RP1 activity; to study signal transduction mechanisms and protein-protein interactions; and to prepare OATP for the uses described below.

Not all expression vectors and DNA regulatory sequences will function 30 equally well to express the DNA sequences of this invention. Neither will all host cells function equally well with the same expression system. However, one of ordinary skill in the art may make a selection among expression vectors, DNA

regulatory sequences, and host cells using the guidance provided herein without undue experimentation and without departing from the scope of the invention.

Polypeptides

This invention further concerns polypeptides comprising all or a portion of the 5 amino acid sequences of OATPs of the present invention. The inventors prefer polypeptides comprising all or a portion of the amino acid sequences shown as in SEQ ID NO:2 (OATP2), SEQ ID NO:4 (OATP-RP2), SEQ ID NO:6 (OATP-RP3), SEQ ID NO:8 (OATP-RP4), SEQ ID NO:10 (OATP-RP5) or SEQ ID NO:12 (OATP-RP1). Where a portion of an OATP of the present invention is used, preferably the 10 portion exhibits the same biological activity of the OATP from which the portion is derived. For example, and within the scope of the invention, are polypeptides that comprise all or a portion of OATP2, OATP-RP2, OATP-RP3, OATP-RP4, OATP-RP5 or OATP-RP1 that exhibit transport activity. The portions may contain one or more mutations so that the protein(s) fail(s) to exhibit transport activity, but that can 15 be used to screen for compounds that will modulate or bind to the protein or portion thereof.

Persons having ordinary skill in the art may prepare these polypeptides by methods known in the art. For example, one may use chemical synthesis, such as the solid phase procedure described by Houghton *et al.* (1985), *Proc. Natl. Acad. Sci.* 82: 20 5131-5. Another method is *in vitro* translation of mRNA. One may also produce the polypeptides in the above-described host cells, which is the preferred method. For example, one may synthesize DNA comprising all or a portion of SEQ ID NO:1, SEQ ID NO:3, SEQ ID NO:5, SEQ ID NO:7, SEQ ID NO:9, or SEQ ID NO:11 by PCR as described above, insert the synthesized DNA into an expression vector, transform a 25 host cell with the expression vector, and culture the host cell to produce the desired polypeptides.

Persons skilled in the art can isolate and purify such polypeptides by any one of several known techniques; for example, ion exchange chromatography, gel filtration chromatography and affinity chromatography. Such techniques may require 30 modification of the protein. For example, one may add a histidine tag to the protein to enable purification on a nickel column.

Persons skilled in the art can use the polypeptides of the invention in a wide variety of ways. For example, one may use them to generate polyclonal or monoclonal antibodies. One may then use such antibodies for immunodetection (e.g., radioimmunoassay, enzyme immunoassay, or immunocytochemistry),

5 immunopurification (e.g., affinity chromatography) of polypeptides from various sources, or immunotherapy.

Persons skilled in the art may make modified OATP polypeptides by known techniques. Such modifications may cause higher or lower activity, permit higher levels of protein production, or simplify purification of the protein. Such

10 modifications may help identify specific OATP amino acids involved in binding, which in turn may help rational drug design of OATP modulators. One can make amino acid substitutions based on similarity in polarity, charge, solubility, hydrophobicity, hydrophilicity and/or the amphipathic nature of the residues involved. For example, negatively charged amino acids include aspartic acid and glutamic acid;

15 positively charged amino acids include lysine and arginine; amino acids with uncharged polar head groups or nonpolar head groups having similar hydrophilicity values include the following: leucine, isoleucine, valine, glycine, alanine; asparagine, glutamine; serine, threonine; phenylalanine, tyrosine. All such modified polypeptides are included within the scope of the invention.

20 Preferred analogs include proteins that differ from the novel OATPs of the present invention (or biologically active fragments thereof) by one or more conservative amino acid substitutions or by one or more non-conservative amino acid substitutions, deletions or insertions which do not abolish the biological activity of the analog. Conservative substitutions typically include the substitution of one amino

25 acid for another with similar characteristics, e.g., substitutions within the following groups: valine, glycine; glycine, alanine; valine, isoleucine, leucine; aspartic acid, glutamic acid; asparagine, glutamine; serine, threonine; lysine, arginine; and phenylalanine, tyrosine. Other conservative amino acid substitutions can be taken from the table below.

30

Table 1
Conservative amino acid replacements

For Amino Acid	Code	Replace with any of:
Alanine	A	D-Ala, Gly, beta-Ala, L-Cys, D-Cys

Arginine	R	D-Arg, Lys, D-Lys, homo-Arg, D-homo-Arg, Met, Ile, D-Met, D-Ile, Orn, D-Orn
Asparagine	N	D-Asn, Asp, D-Asp, Glu, D-Glu, Gln, D-Gln
Aspartic Acid	D	D-Asp, D-Asn, Asn, Glu, D-Glu, Gln, D-Gln
Cysteine	C	D-Cys, S-Me-Cys, Met, D-Met, Thr, D-Thr
Glutamine	Q	D-Gln, Asn, D-Asn, Glu, D-Glu, Asp, D-Asp
Glutamic Acid	E	D-Glu, D-Asp, Asp, Asn, D-Asn, Gln, D-Gln
Glycine	G	Ala, D-Ala, Pro, D-Pro, β -Ala, Acp
Isoleucine	I	D-Ile, Val, D-Val, Leu, D-Leu, Met, D-Met
Leucine	L	D-Leu, Val, D-Val, Met, D-Met
Lysine	K	D-Lys, Arg, D-Arg, homo-Arg, D-homo-Arg, Met, D-Met, Ile, D-Ile, Orn, D-Orn
Methionine	M	D-Met, S-Me-Cys, Ile, D-Ile, Leu, D-Leu, Val, D-Val
Phenylalanine	F	D-Phe, Tyr, D-Thr, L-Dopa, His, D-His, Trp, D-Trp, Trans-3,4, or 5-phenylproline, cis-3,4, or 5-phenylproline
Proline	P	D-Pro, L-1-thioazolidine-4-carboxylic acid, D- or L-1-oxazolidine-4-carboxylic acid
Serine	S	D-Ser, Thr, D-Thr, allo-Thr, Met, D-Met, Met(O), D-Met(O), L-Cys, D-Cys
Threonine	T	D-Thr, Ser, D-Ser, allo-Thr, Met, D-Met, Met(O), D-Met(O), Val, D-Val
Tyrosine	Y	D-Tyr, Phe, D-Phe, L-Dopa, His, D-His
Valine	V	D-Val, Leu, D-Leu, Ile, D-Ile, Met, D-Met

Other analogs within the invention are those with modifications which increase protein or peptide stability; such analogs may contain, for example, one or more non-peptide bonds (which replace the peptide bonds) in the protein or peptide sequence. Also included are analogs that include residues other than naturally occurring L-amino acids, e.g., D-amino acids or non-naturally occurring or synthetic amino acids, e.g., β or γ amino acids.

The inventors contemplate a number of other variations of the above-described polypeptides. Such variations include salts and esters of the polypeptides, as well as precursors of the aforementioned polypeptides (e.g., having N-terminal substituents such as methionine, N-formylmethionine and leader sequences). The invention includes all such variations.

Method for detecting nucleic acids

The present invention further concerns a method for detecting nucleic acids encoding OATP proteins. In this method, a person of ordinary skill in the art (a) contacts nucleic acids of unknown sequence with a nucleic acid having a sequence

complementary to a known coding sequence (e.g., a sequence of at least about 10 nucleotides from, e.g., SEQ ID NO:1, SEQ ID NO:3, SEQ ID NO:5, SEQ ID NO:7, SEQ ID NO:9, or SEQ ID NO:11, particularly the coding regions thereof), wherein the latter nucleic acid has a detectable marker; and (b) determines the presence of 5 marker bound to any of the nucleic acids of unknown sequence. The presence of bound marker indicates the presence of the desired nucleic acids. One can apply this method to detect OATP nucleic acids from other tissues (which may have different regulatory elements) and nucleic acids from other species (e.g., monkey).

Persons of ordinary skill in the art generally know how to obtain nucleic acids 10 to be analyzed in this method. For genomic DNA, one can rapidly freeze tissue, crush the tissue into readily digestible pieces, and incubate the crushed tissue in proteinase K and SDS to degrade most cellular proteins. One can then deproteinize the genomic DNA by successive phenol/chloroform/isoamyl alcohol extractions, recover DNA by ethanol precipitation, dry it and resuspend it in buffer. For RNA, one can lyse 15 cultured cells in 4M guanidinium solution, draw the lysate through a 20-gauge needle, pellet the RNA through a cesium chloride step gradient, and remove the supernatant. The pellet should contain purified RNA.

The detectable marker may be a radioactive ion linked to one of the 20 nucleotides of the complementary nucleic acid. Common radioactive labels are ^{32}P and ^{35}S , although one may also use other labels such as biotin. Persons skilled in the art are aware of various methods to attach the labels to the complementary nucleic acid (e.g., the random primer method for attachment of ^{32}P or ^{35}S).

Persons of ordinary skill in the art generally know how to carry out such a 25 method of detecting nucleic acids. For example, one may perform a Southern or northern blot using a radiolabeled OATP complementary oligonucleotide probe. One can then detect hybridization by autoradiography. Depending on the marker, one may also use other detection methods (e.g., spectrophotometry).

Methods for detecting OATP modulators and compounds transported by the
OATPs of the present invention

30 This invention further concerns methods for detecting modulators of the OATPs of the present invention, as well as methods for detecting compounds that are transported by the OATPs of the present invention (e.g., compounds that are

transported into the liver that may be used as carriers for other compounds). A screen for OATP modulators entails detecting binding of molecules (e.g., polypeptides, natural products, synthetic compounds) in cells expressing OATP protein.

Alternatively, a screen for OATP positive modulators and/or negative modulators
5 entails detecting the augmentation and/or inhibition of transport of a known compound. A screen for OATP-transported compounds entails detecting the transport of molecules (e.g., polypeptides, natural products, synthetic compounds) by an OATP.

Cloning and sequencing of the OATPs of the present invention enables construction of cells useful in screening for natural products and synthetic compounds
10 that bind to, modulate, and/or are transported by OATP activity. A process for detecting OATP modulators requires transforming a suitable vector into compatible host cells as described previously herein. One treats such transformed cells with test substances (e.g., synthetic compounds or natural products), and then measures activity in the presence and absence of the test substance.

15 **OATP Assay**

An assay for the measurement of OATP activity is performed as follows:
HEK293 cells are plated in Dulbeccos Modified Eagles Medium (DMEM) plus 10% fetal bovine serum plus penecillin and streptomycin, in poly-d-lysine coated dishes and co-transfected with OATP transporter expression plasmids using Lipofectamine
20 Plus (Life Technologies, Inc.). The cells and media are assayed for substrate transport 24 hours later. Alternatively, cell lines engineered to stably express OATPs could be plated and assayed directly without transfection. To measure transport, media is removed and monolayers are assayed in triplicate by washing once in serum-free DMEM and adding the same medium containing [³H]-substrate alone or in the
25 presence of various concentrations of unlabeled test compounds. For OATP2, the [³H]-substrate could be [³H]-pravastatin, [³H]-taurocholate, or [³H]-dehydroepiandrosterone sulfate, or [¹²⁵I]-thyroid hormone (T4). Monolayers are incubated at room temperature for 5 to 10 minutes depending on the transporter. Then the cells are rapidly washed once with ice cold DMEM containing 5% BSA,
30 twice with DMEM plus 0.1% BSA and once with DMEM alone. Cells are lysed in 0.1 N NaOH and a fraction of the lysate is used to determine radiolabel incorporation by liquid scintillation counting, and another is used to determine protein concentration

in the lysate using the Bradford assay with BSA as a standard. The transport activity is expressed as moles of substrate transported into cells/mg of cell protein/minute.

Drug Targeting

Also included within the present invention is tissue expression of an OATP of the present invention. The OATPs of the present invention are also useful for targeting drugs to certain organs that express an OATP described herein (e.g., the liver), and for modulating the concentration of endogenous substrates.

For example, the novel organic anion transporter disclosed herein, OATP2, represents a potential therapeutic target due to its ability to modulate the cellular uptake and potential secretion of several biologically important organic anions, including bile acids and the androgen hormone dehydroepiandrosterone sulfate (“DHEAS”). Furthermore, since OATP2 transports at least one drug (i.e. pravastatin), and other members of this family are known to transport a variety of other xenobiotics, this transporter could be exploited to optimize the delivery of drugs into liver and away from other tissues.

OATP2 is unique among the OATP family, in that it is the only known organic anion transporter that is expressed exclusively in the liver. Thus, drugs optimized for this transporter could be targeted for hepatic delivery with greater selectivity than with any other known transporter. To generalize this approach, it may be possible to identify a small molecule “adaptor” that is efficiently recognized and transported by OATP2 (an OATP2-transported compound) that could be appended to other drugs for hepatic targeting even if the parent compound is not transported by OATP2.

Alternatively, if a therapeutic compound is taken up into the liver entirely or substantially by OATP2, one could inhibit hepatic clearance and thereby elevate circulating concentrations, or increase the compounds half-life in the periphery, by adding a functionality to said compound that disallows transport by OATP2. Likewise, if an endogenous substance utilizes OATP2 for liver uptake and clearance from the circulation, a competitive or non-competitive OATP2 inhibitor could elevate plasma levels of said substance. As an example, DHEAS is an adrenal androgen that declines with age and on the basis of some animal data, it has been suggested that replacement of DHEAS deficiency may stimulate age-related immune deficiencies,

increase cognitive function and insulin sensitivity, and maintain bone mass. Inhibiting the hepatic clearance of endogenous DHEAS through blocking its interactions with OATP2 could result in elevated hormone levels in the absence of hormone supplementation.

5 With the information provided herein, one skilled in the art is able to identify molecules, both naturally occurring and synthetic (including therapeutic drugs), that are transported by the OATPs, e.g., OATP2, disclosed herein. OATPs as a class generally exhibit broad substrate specificity ("polyspecific" transporters). Thus, it is anticipated that many additional substrates of these transporters will be identified.

10 Gene Therapy

Persons skilled in the art can also use sense and antisense nucleic acid molecules as therapeutic agents for OATP-related indications. One may construct vectors that direct the synthesis of the desired DNA or RNA or formulate the nucleic acid as described in the art.

15 Several references describe the usefulness of antisense molecule. See Toulme and Helene (1988), Gene 72: 51-8; Inouye (1988), Gene, 72: 25-34; Uhlmann and Peyman (1990), Chemical Reviews 90: 543-584; Biotechnology Newswatch (January 15, 1996), p. 4; Robertson, Nature Biotechnology 15: 209 (1997); Gibbons and Dzau (1996), Science 272: 689-93. One can design them based on genomic DNA and/or
20 cDNA, 5' and 3' flanking control regions, other flanking sequences, intron sequences, and nonclassic Watson and Crick base pairing sequences used in formation of triplex DNA. Such antisense molecules include antisense oligodeoxyribonucleotides, oligoribonucleotides, oligonucleotide analogues, and the like, and may comprise at least about 15 to 25 bases.

25 Antisense molecules may bind noncovalently or covalently to the OATP DNA or RNA. Such binding could, for example, cleave or facilitate cleavage of OATP DNA or RNA, increase degradation of nuclear or cytoplasmic mRNA, or inhibit transcription, translation, binding of transactivating factors, or pre-mRNA splicing or processing. Antisense molecules may also contain additional functionalities that
30 increase stability, transport into and out of cells, binding affinity, cleavage of the target molecule, and the like. All of these effects would decrease expression of OATP protein and thus make the antisense molecules useful as OATP modulators.

EXAMPLES

The following examples are included for understanding the present invention and are not intended to limit the scope of Applicants invention, which is defined
5 solely by the claims.

Example 1

Isolation of OATP2, OATP-RP1, OATP-RP2, OATP-RP3, OATP-RP4 and OATP-RP5 full length cDNAs and cloning into mammalian expression vectors

Human OATP2 was identified by searching the public EST databases for sequences homologous to human OATP. One EST sequence, Genbank accession number T73863, encoded a partial cDNA with significant sequence identity with OATP. EST sequences encoding partial cDNAs for OATP-RP1, OATP-RP2, OATP-RP3, OATP-RP4, and OATP-RP5 were identified by searching the public EST databases and the Incyte, Inc. EST database for sequences homologous to human OATP. The EST clone IDs corresponding to OATP-RP1 are 820117, 2668489, 1610706, 2972518, and 588148. These clones represent a contig encoding only part of the full length cDNA. The Incyte EST clone IDs corresponding to OATP-RP2 are 1664737 and 2641944. These clones represent a contig encoding only part of the full length cDNA. The Incyte EST clone IDs corresponding to OATP-RP3 are 2493241, 2497845, and 2664024. These clones represent a contig encoding only part of the full length cDNA. The Incyte EST clone IDs corresponding to OATP-RP4 are 1494683 and 1685219. These clones represent a contig encoding only part of the full length cDNA. The Incyte EST clone ID corresponding to OATP-RP5 is 925716. This clone encodes only part of the full length cDNA. Full length clones for each of the above genes were obtained using the Gene Trapper cDNA Positive Selection System (LifeTechnologies, Inc.). In this procedure, a single or multiple oligonucleotides complementary to each of the EST contigs or individual EST sequences, were biotinylated at the 3'-end and used to hybridize to a single-stranded human cDNA library constructed in pCMVSport2 (LifeTechnologies, Inc.). The sequence of oligonucleotides used for each gene as well as the tissue source of the libraries screened are shown in Table 2.

Table 2

Oligonucleotides used to screen for OATP Full length cDNAs using Gene-Trapper
Selection

Gene	Biotinylated capture oligonucleotide(s) used	Seq ID number of oligonucleotide	Human cDNA library screened
OATP2	5'-ACCTGTCTAGCAGGTTGCA-3'	13	liver
OATP-RP1	5'-CTGTCGGAGTCTTCAGATG-3'	14	brain
OATP-RP2	5'-TCCATCACAGCCTCCTACGC-3'	15	liver
OATP-RP3	5'-TGCCTCTACTCTGACCCTAG-3'	16	heart
OATP-RP4	5'-GGAGCAGTCATTGACACCAC-3'	17	
	5'-TGCTGGGAGTACAACGTGACG-3'	18	heart
	5'-ACAAGGAGGATGGACTGCAG-3'	19	
OATP-RP5	5'-CAGGAATCCCAGCTCCAGT-3'	20	
	5'-GCTACAACCCAACACTGGC-3'	21	brain
	5'-GGGACTAACTGTGATACTGG-3'	22	

Hybrids between the biotinylated oligonucleotides and single-stranded cDNA were captured on streptavidin-coated paramagnetic beads. After washing, the captured single-stranded cDNA targets was released from the biotinylated oligonucleotides and converted to dsDNA by DNA polymerase using the corresponding unbiotinylated oligonucleotide. Following transformation and plating, several positive clones for each gene were identified by PCR analysis. Full-length cDNA clones were identified by sequencing. In the case of OATP-RP1, a partial cDNA was obtained by the above technique (pSP-RP1A). Another cDNA clone that was part of the OATP-RP1 contig was identified by searching the public EST databases (Genbank accession number AI027850). An EcoRI-NotI fragment of this clone containing the first 477 nucleotides of OATP-RP1 (SEQ ID NO: 11) (obtained from Research Genetics, Inc.) was ligated to EcoRI-Not I digested pSP-RP1A to generate the full length sequence.

Two polymorphic positions were identified when sequencing multiple OATP-RP4 cDNA clones. Thus, nucleotide number 713 of SEQ ID NO: 7 can be either a C, encoding Leu in SEQ ID NO:8, or a T, encoding a Phe in SEQ ID NO:8. Similarly, nucleotide number 2397 of SEQ ID NO: 7 can be either a G, encoding a Gly in SEQ ID NO:8 , or a T, encoding a Val in SEQ ID NO:8.

For expression studies, OATP2 cDNA was cloned into the expression vector pCEP4βR, a modified form of pCEP4 (Invitrogen, Inc.) in which the CMV promoter-driven expression cassette has been inverted, and used in transient transfections. To accomplish this, OATP2 cDNA in pCMVSport2, correponding to nucleotides 59

through 2361 of SEQ ID NO:1, was excised by digestion with KpnI and NotI. This fragment was cloned into KpnI-NotI digested pCEP4 β R. This clone, pCEP-OATP2 was used for transient transfection expression studies.

5

Example 2

Tissue and cellular distribution of OATP2, OATP-RP1, OATP-RP2, OATP-RP4, and OATP-RP5

The tissue distribution of OATP2, OATP-RP1, OATP-RP2, OATP-RP4, and OATP-RP5 expression was determined by Northern blotting of poly A+ RNA from a variety of human tissues (Figure 1). Transporters of this family previously described in the literature, namely human OATP, rat oatp1, rat oatp2 and rat oatp3, are all expressed in liver, kidney and brain. All of the above transport bile acids as well as a variety of other substrates that are specific for subsets of these transporters. In contrast, the expression of OATP2, which also transports bile acids, is very hepato-specific; a major 3.2 kb and several minor hybridizing bands were observed only in RNA from liver and no other tissue. The specific cell types that express this transporter were examined by *in situ* hybridization of OATP2 riboprobe to human liver samples. Strong hybridization signal was seen localized to hepatocytes throughout the liver lobule with no significant difference in signal intensity among centrilobular, midzonal or periportal regions. No signal was observed in bile ducts, Kupffer cells, or blood vessels, nor in any cell types from human lung (data not shown).

OATP-RP1 is expressed in nearly all tissues tested with highest abundance in skeletal muscle, lung, placenta, and heart. OATP-RP2 is ubiquitously expressed in all tissues tested. OATP-RP4 has a much more restricted pattern of expression with abundant transcripts in skeletal muscle and heart and much less in prostate and thymus. The expression of OATP-RP5 is likewise tissue specific, with brain and testes being the only sites where transcripts were detected.

30

Example 3

Expression of OATP2 in transfected cells

293EBNA cells (Invitrogen, Inc.), an HEK293 cell derivative, were transiently transfected with the OATP2 expression vector pCEP-OATP2, or the pCEP4 vector

alone (MOCK) and the transport of [³H]-labeled substrates was determined 24 hours later. Figure 2A shows specific uptake of [³H]-pravastatin and [³H]-DHEAS. Figures 2B and 2C show the specific uptake of [³H]-taurocholate and [¹²⁵I]-thyroid hormone (T4), respectively. The uptake of radiolabeled substrate for 5 minutes into cells
5 transfected with pCEP-OATP2 or empty vector (MOCK) was determined in the absence (solid bars) and presence (open bars) of excess unlabeled substrate. Thus, OATP2 is a liver specific human transporter of at least some HMG CoA reductase inhibitors, bile acids, adrenal steroids, and thyroid hormone.